EVALUATING THE USE OF A VIRTUAL REALITY PATIENT SIMULATOR AS AN EDUCATIONAL TOOL IN AN AUDIOLOGICAL SETTING

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Abstract

There is currently an international shortage of Audiologists (McIntyre, 2010). Audiology is a professional degree undertaken at a postgraduate level at most universities around the world. Students have training in anatomy and physiology, hearing aids, cochlear implants, electrophysiology and acoustics; combined with a clinical component to the course. The clinical component is undertaken throughout the entirety of the course and involves a mixture of observation and supervised clinical practice in a variety of settings.

Clinical training often begins with students crowded around a single piece of equipment, such as an audiometer for testing puretone-hearing thresholds or by pairing up and simulating a hearing loss. This process creates time and access constraints for students as it restricts their ability to practice performing audiometry, particularly if there is a shortage of equipment, and also limits their exposure to a wide variety of hearing loss pathologies.

The potential for universities worldwide to use Virtual Reality and Computer Based Simulations to provide Audiology students with basic clinical skills without relying on extensive support from external clinics warrants further investigation. In particular, it needs to be determined whether Audiology students value these simulations as a useful supplement to their clinical training, and whether the use of these simulations translates into measurable improvements in student abilities in real clinical placements.

A computer based training program for Audiology students developed at the Human Interface Technology Lab (HITLAB) New Zealand is evaluated in this study as an educational tool at the University of Canterbury, New Zealand. The present study aims to determine if a sample of twelve first year Audiology students felt their interactions with Virtual Patients improved their ability to interact with clients and perform masking which is often part of a basic

audiometric assessment for a patient with hearing loss. The study measures the students' competency in performing masking in puretone audiometry on the Virtual Patient and then on a patient in a real-world setting to see whether the Audiology Simulator training tool improved the student's basic audiometry skills (a training effect) and whether these skills were maintained after a period of four weeks (a maintenance effect).

Statistical analysis is applied to determine any training and maintenance effects. Students also gave subjective feedback on the usefulness of the simulator and suggestions for ways in which it could be improved.

Results indicated that there was no statistically significant training effect between students that had used the Audiology Simulator and those that hadn't. Once all students had used the Virtual Patient there was an overall maintenance effect present in that student's scores stayed the same or improved even for those students who had not used the Virtual Patient for a period of time. Students overall reported that they found the Virtual Patient to be 'Moderately Useful' and had many recommendations for ways in which it could be improved to further assist their learning.

The present study indicates that computer based simulation programs like the Virtual Patient are able to present and simulate realistic hearing losses to an acceptable level of complexity for students studying in the field of audiology and that the Audiology Simulator can be a useful and complementary training tool for components of audiological clinical competence, such as puretone audiometry and masking.

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Introduction

The Profession of Audiology

Audiologists are health professionals dedicated to the assessment, identification, and treatment of disorders of hearing and balance. Audiologists work in a range of settings, including the public, private and educational sectors, as well as in research. Audiologists are involved in the recommendation and programming of hearing aids and mapping of cochlear implants. They are involved in counseling families through a new diagnosis of hearing loss in infants and teach coping and compensation skills to adults suffering from hearing loss. Audiologists may also work closely with those involved in Deaf Education and with medical specialists in the field of Ear, Nose and Throat medicine.

Training

The first university course for Audiologists was offered by Carhart at Northwestern University in 1946 which arose because of a need for amplification in the form of hearing aids for the returned soldiers from World War II. (Newby, 1972). Currently, an Audiologist usually graduates with one of the following qualifications (Master of Science (Audiology) AuD, PhD or ScD) depending on the country and the program attended by the student. The Master of Audiology Degree (MAud) is the required qualification to become an Audiologist in New Zealand. There is currently a shortage of Audiologists both nationally and internationally (McIntyre, 2010).

The MAud degree is a two-year professional postgraduate program undertaken after the completion of an undergraduate degree. Students have detailed and specific training in anatomy and physiology, hearing aids, cochlear implants, electrophysiology and acoustics; combined with a clinical component to the course. The clinical component is undertaken throughout the entirety of the course and involves a mixture of observation and supervised clinical practice in a variety of settings. Students come from a variety of undergraduate backgrounds, including psychology, biology, speech and language therapy and engineering.

Lack of Audiologists

There is a need for more trained Audiologists with our increasingly aging society and now that newborns are being identified earlier with hearing loss. It is estimated that there are at least 450,000 people in New Zealand with some form of hearing difficulty according to the Hearing Association of New Zealand (2012). At present, there are approximately 150 fully qualified Audiologists registered as members of the New Zealand Audiological Society, which translates to approximately 1 Audiologist per 3000 people with hearing loss. Whilst this reflects a lower workforce than required, the need is expected to grow. With an increasingly aging society in New Zealand (Gorman & Brooks, 2009), hearing loss will become more prevalent which means that there is an increasing need in the future for more people to be trained in the profession of audiology to help those suffering with hearing loss.

For example, in May 2006 the New Zealand Government announced that it would fund a universal newborn hearing-screening program (NBHS) for all New Zealand children. The screening was rolled out across the District Health Boards (DHBs) over a number of years and was eventually available nationwide for all children in 2010. Hearing loss in neonates is the most common congenital sensory disorder. Research has placed the prevalence of significant permanent hearing loss in neonates as 1-2 per 1000 live births (Wrightson, 2007). Approximately 170 children per year are born in New Zealand with permanent congenital hearing loss (Ministry of Health, 2009). Before the screening program was introduced, the average age for the detection of permanent hearing loss (which was moderate or greater in severity) was between 3 and 4 years of age (Ministry of Health, 2009). This meant that when children were finally diagnosed with a hearing impairment they were often behind their peers in many areas of development, particularly language acquisition, and consequently they often were not able to ever catch up. The introduction of a NBHS means that early detection and intervention of hearing loss is possible and the babies that are diagnosed with hearing loss now may have a much greater chance of reaching their full potential. Screening programs such as this one described in New Zealand are beginning to emerge internationally which is also leading to a greater number of people being identified with hearing loss earlier than they otherwise would have been (Thompson, McPhillips, Davis, Lieu, Homer & Helfland, 2001). This indicates that there will be an even greater need in the future for clinically trained Audiologists as well as PhD researchers in audiology and hearing science.

If there are not enough Audiologists trained worldwide to cope with the increasing population with hearing loss there are several possible consequences. One is that young children may go untreated for hearing loss that has been identified using the NBHS (Helfand et al, 2001). This can have detrimental effects on their speech and language development for the child if they don’t receive amplification from an early age (Lennerberg, 1967; Helfand et al, 2001). There is ample evidence for the critical period hypothesis (Lenneberg, 1967; Helfand et al, 2001); which states that the first few years of life is the crucial time in which an individual can acquire a first language if presented with adequate stimuli. If language input doesn’t occur until after this time, the individual will never achieve a full command of language. A recent study showed prelingually deaf children who undergo cochlear implantation at younger ages reportedly achieve greater speech perception skills than those who undergo implantation at a later age (Cheng, Grant & Niparko, 1999). One of the difficulties in training enough Audiologists is that training requires extensive clinical practice and this may prove expensive and may be limited by a number of factors.

Clinical Training and Assessment Methods in Audiology

In the setting of clinical medical education, there are few studies that have described audiology training specifically, although studies of clinical medical education describe various teaching methods that are closely related, for example when the technique or skill is usually demonstrated by the instructor or supervisor before being attempted by the student under supervision. The student may practice the skill or technique on a mannequin or a fellow student before interacting with a real patient. A study by Cooper & Taqueti (2004) described some of the different training methods for clinical education and training. These included verbal (role playing); standardised patients (actors); part-task trainers (physical, virtual reality); computer patient (computer screen, screen based 'virtual world') and electronic patient (replica of clinical site, mannequin based, full virtual reality).

Current simulation software for audiology training has a limited human-computer interface, which restricts the student's ability to transfer the skills that they have learned to real clients (Clyman & Orr 1990; McGaghie 1999). In recent years, the Parrot Software has been used at the University of Canterbury to assist in training students and assessing them in their puretone-masking test. The software involves a simulation of basic audiological tests including pure-tone audiometry, speech reception threshold (SRT), and immittance audiometry. Within the Parrot Software there are 100 clinical cases available for the students to test. The Parrot software is an open source project distributed with a free software license, making Parrot free software. The parrot software is fast becoming outdated with the arrival of new training technology, in the form of Virtual Patients.

Assessment of the skills learned by students in clinical education often takes the form of an Objective Structured Clinical Examination (OSCE). The students in this study will be measured on the practical skills that they gain from the simulator in the style of a mini-OSCE, focusing on the skills that they have been practicing using the Virtual Patients. This type of examination is currently being used in many of the health science services, such as audiology, midwifery, orthoptics, optometry, medicine, chiropractic, physical therapy, radiography, nursing, pharmacy, dentistry, paramedicine and veterinary medicine (Ross, Carroll, Knight, Chamberlain, Fothergill-Bourbannais & Linton, 1998). It is designed to test clinical skill performance and competence in skills such as communication, clinical examination, medical procedures/prescription, exercise prescription, joint mobilization/manipulation techniques, radiographic positioning, radiographic image evaluation and interpretation of results. An OSCE usually comprises a circuit of short stations (the usual is 5–10 minutes although some use up to 15 minutes), in which each student is examined on a one-to-one basis with one or two impartial examiner(s) and either real or simulated patients (actors). Each station has a different examiner, as opposed to the traditional method of clinical examinations where a candidate would be assigned to an examiner for the entire examination. Candidates rotate through the stations, completing all the stations on their circuit. In this way, all candidates take the same stations. It is considered to be an improvement over traditional examination methods because the stations can be standardised enabling fairer peer comparison and complex procedures can be assessed without endangering patient's health.

As the name suggests, an OSCE is designed to be:

Objective - all candidates are assessed using exactly the same stations (although if real patients are used, their signs may vary slightly) with the same marking scheme. In an OSCE, candidates get marks for each step on the mark scheme that they perform correctly, which therefore makes the assessment of clinical skills more objective, rather than subjective, which is where the examiners decide whether or not the candidate fails based on their subjective assessment of their skills.

Structured - stations in OSCEs have a very specific task. Where simulated patients are used, detailed scripts are provided to ensure that the information that they give is the same to all candidates, including the emotions that the patient should use during the consultation. Instructions are carefully written to ensure that the candidate is given a very specific task to complete. The OSCE is carefully structured to include parts from all elements of the curriculum as well as a wide range of skills.

A Clinical Examination - the OSCE is designed to apply clinical and theoretical knowledge. Where theoretical knowledge is required, for example, answering questions from the examiner at the end of the station, the questions are standardised and the candidate is only asked questions that are on the mark sheet and if they are asked any others then there will be no marks for them.

Computer Based Simulations

Computer based simulations (CBS) are computer programs that simulate the practices and protocols of actual clinical testing. The student is required to complete their testing on CBS in a very similar manner as they would on a real patient/client. The development of full-scale patient simulators started in the 1960s (Abrahamson & Wallace 1980) in the United States of America, with much of the subsequent research centering on medical students (Srinivasan, Hwang, West & Yellowless, 2006). The outcomes of this research have been generally positive with regard to student learning and experiences of the process.

There has been a significant increase in usage and interest in CBS to enhance instruction in education. With the rise in interest and usage of CBS one may be intrigued as to how the simulations are helping to improve teaching and learning. Much of the literature on instructional simulations either reports quantitative reports of how much (or how little) simulations help students learn (Baillie et al, 2000; Mangan, 2003; Kneebone, 2000; Boyd & Jackson, 2004; Turkle, 2004) whilst other literature discusses theoretical views on the use of simulations (Lederman et al, 1999, Baillie et al, 2000, Orrill et al 2001, Yeh, 2004; Mangan, 2003; Kneebone, 2000; Boyd & Jackson, 2004; Turkle, 2004).

Simulations have often been compared with other instructional methods in order to identify their comparative instructional effectiveness and impact upon the learning approach. Several advantages and limitations of instructional simulations have been discussed in the literature. Among the advantages, simulations have the potential to do the following:

1) Improve teaching aims and methods (Lederman et al, 1999, Baillie et al, 2000, Orrill et al 2001, Yeh, 2004) by providing a structured framework for the students when they are practicing different aspects of audiological testing, whether it be puretone audiometry, immittance testing, case history or otoscopy. It can also provide a structured framework for the supervisor or teacher to see how well each student has performed and provide indiviualised feedback.

2) Improve learning and practice (Baillie et al, 2000; Mangan, 2003; Kneebone, 2000; Boyd & Jackson, 2004; Turkle, 2004) by catering to different learning styles in its multi-modality. It also engages students by allowing them to participate in testing rather than simply observing and since it is a computer simulation the students are less afraid to make mistakes and this in turn leads to it being able to

3) Motivate students (Reigeluth et al 1989; Baillie et al, 2000; Yarger et al, 2003; Mitchell, 2004) to practice their clinical skills.

4) It has the obvious benefit of saving operational cost and time (Lederman et al, 1999; Mangan, 2003; West & Graham, 2005) by being portable. A computer-based simulation allows students to practice at home and in any environment they choose since they don't have accessibility constraints because the computer simulation doesn't limit them to a clinical environment, such as a hospital or university. This improves their opportunities for learning.

5) It can increase safety (Mangan, 2003, West & Graham, 2005) for patients since students are learning via simulation before seeing real clients in a health setting.

A study by Lieberth & Martin (2005) reported on the instructional effectiveness of a web-based pure-tone audiometry simulator for undergraduate and graduate students in speech language therapy. Graduate and undergraduate majors in communication disorders practiced giving basic hearing tests on either a virtual web-based audiometer or a portable audiometer. Each group evaluated competencies in basic testing skills and results indicated that both undergraduate and graduate students learned basis audiometric testing skills using the virtual audiometer. These skills were generalised to basic audiometric testing skills required of a speech language therapist using a portable audiometer. Their study found that students who were trained on the virtual audiometer demonstrated less well-developed competencies in those areas requiring patient contact, for example, things like giving directions or determining the better ear.

Another study by Alinier, Hunt, Gordon & Harwood (2006) investigated the effectiveness of computer simulation training technology in undergraduate nursing education. A pre-test/post-test design was employed with 99 volunteer undergraduate students taking part. Students were assigned to either a control group or the experimental group. After completing a pre-test, the experimental group was exposed to simulation training as well as following their normal curriculum, whilst the control group simply followed the normal curriculum. Subsequently, all students were tested again and completed a questionnaire. In the final test, both the control and the experimental groups improved their performance on their Objective Structured Clinical Examination (OSCE). Mean test scores increased by 7.18 percent for the control group and 14.18 percent for the experimental group, which is statistically significant. However, students' perceptions of stress and confidence (measured on a 5 point Likert scale) were very similar between the groups. This study concluded that computer simulation training is a useful training technique that enables small groups of students to practice in a safe and controlled environment on how to react adequately in a critical patient care situation. They noted that this type of training has the potential to be very valuable in its ability to equip students with a minimum of technical and non-technical skills before they want to use them in real life settings (Alinier et al, 2006).

Computer based education has the opportunity to cater to the different learning styles of individuals by being multimodal in its teaching style. Information can be transferred to the student by visual, aural, written and kinesthetic or interactive methods making it suitable to a range of individuals with different learning styles. However, it lacks the real time interaction and feedback one would receive with a teacher or instructor in a traditional classroom environment. So, whilst computer based instruction can provide different ways to study material, all students may not prefer this type of instruction. Just like there are auditory learners and visual learners when dealing with lecture-based instruction, there are individuals who prefer computer-based instruction and those who prefer instructor-based instruction (Cook, D. A., Levinson, A. J., Garside, S., Dupras, D. M., Erwin, P. J. & Montori, V. M., 2008).

Studies that have focused primarily on learning styles and computer program interaction have shown that individuals with particular dominant learning styles interact differently whilst working through computer programs. These studies have placed the different learning styles into two main categories of field-dependent and field-independent learning styles. Reed, Oughton, Ayersman, Ervin and Giessler (2000) defined the two categories. They described field-dependent people as tending to rely more on external references; and in contrast, field-independent people tend to focus more on internal references. The field-dependent person will see an object as a whole, and are more likely to appreciate the big picture when they are learning; whereas, the field-independent person focuses on individual parts of the object, and will be more interested in the specific details that make up the big picture.

Research has shown that field-dependent learners take more linear steps when working through computer programs than field-independent learners (Reed and Oughton, 1997; Reed et al., 2000). The authors also found that individuals with more years of computer experience took more linear steps than those with less years of experience. Since field-dependent persons seem to go from one topic to another in an ordered sequence and the field-independent person seems to be more willing to explore without following a particular sequence, it is important to take these considerations into account when designing a computer based program for learning.

Research has also shown that learning styles are not inflexible, meaning they can be changed or modified to adapt to different learning situations (Grasha, 1996; Lynch et al., 2001; Rasmussen & Davidson-Shivers, 1998). Educators must acknowledge that students have different learning styles and accommodate the students who have difficulty with strictly computer-based instruction. This could potentially be a problem for some students who have returned to study at a postgraduate level after a number of years and do not feel comfortable with the level of technology that is demonstrated in using a Virtual Patient. The proper introduction to the computer program could possibly further enhance the individuals' overall perception of the computer program (Shaw & Marlow, 1999).

This is important to consider in the development of computer based training programs in audiology because currently many of the students undertaking the professional postgraduate program of audiology have been out of study for a number of years and some may not have had much exposure to using computers and using computer programs. Some students may feel intimidated by the software at first whilst it is unfamiliar and so a basic introduction with lots of support available is preferable. The Audiology Simulaor to receive evaluation within this thesis has been designed specifically for the field of audiology, and the training of students in this field. There are several other themes that have predicted success for students that are using Computer Based Simulation programs as part of clinical training and education in the health field (Rochelle et al, 2000; West & Graham, 2005).

The following themes emerged from the work of Rochelle et al (2000) and West and Graham (2005) when looking at the potential for educational technology to improve teaching and learning; *Visualisation*: Use of technology should help illustrate visually to the students the theory behind the technique. *Authentic Engagement*: Students should be actively engaged in the learning process rather than passive receivers of knowledge. Engagement is also more meaningful if it is authentic or similar to real life experiences. *Quality and Quantity of Practice and Feedback*: Technology can be used to provide more quality practice opportunities that are of a higher quality. *Interaction and Collaboration*: Technology can be used to provide students the opportunity to interact with each other or with the instructor. *Reflection*: The use of the technology should "support meaningful student reflection". Schon (1987) discussed two types of reflection: “reflection-on-action” which is when a person reflects back on actions they have taken in the past and “reflection-in-action” which occurs when a person reflects on their actions as they are in the midst of performance or decision making.

Studies investigating the usefulness of Computer Based Simulations have shown that students might react similarly to real and simulated patients (Sanson-Fisher & Poole 1980). In the study by Edelstein et al. (2000), students thought that Computer Based Simulations were better tests of clinical decision-making than written shelf examinations. In a special themed article, Holmboe (2004) stated that Virtual Patients and other simulation technologies are considered as being important and reliable tools for teaching clinical skills and evaluating competence but also emphasised that they cannot substitute to the direct observation by faculty of trainees’ clinical skills with actual patients.

Simulated patients have therefore been suggested to be useful as assessment tools in Objective Structured Clinical Examinations or in other assessment methods in evaluating students’ interactions with patient related medical issues, such as clinical reasoning and/or medical problem solving abilities (Collins 1998; Schuwirth & Van der Vleuten 2003). More recently, Virtual Patients have been gradually introduced as a complementary method to simulated patients because they support active and reflective learning (Clyman & Orr 1990; McGaghie 1999). The incorporated feedback helps with this reflective learning, where students are able to see where they have made mistakes and what their results should look like if they don’t match up.

One approach to training as specified by the Research Triangle Institute developed by Hubal and his colleagues (2000) is illustrated in *Figure 1*. They believe that this approach is compatible both with training technical skills such as puretone audiometry and masking as well as soft skills like interviewing and developing a personal rapport with the patient. Using this model, virtual training would serve to provide students with a learning environment, which enabled them to become familiar with the audiometer and protocols whilst they acquire and practice their skills.

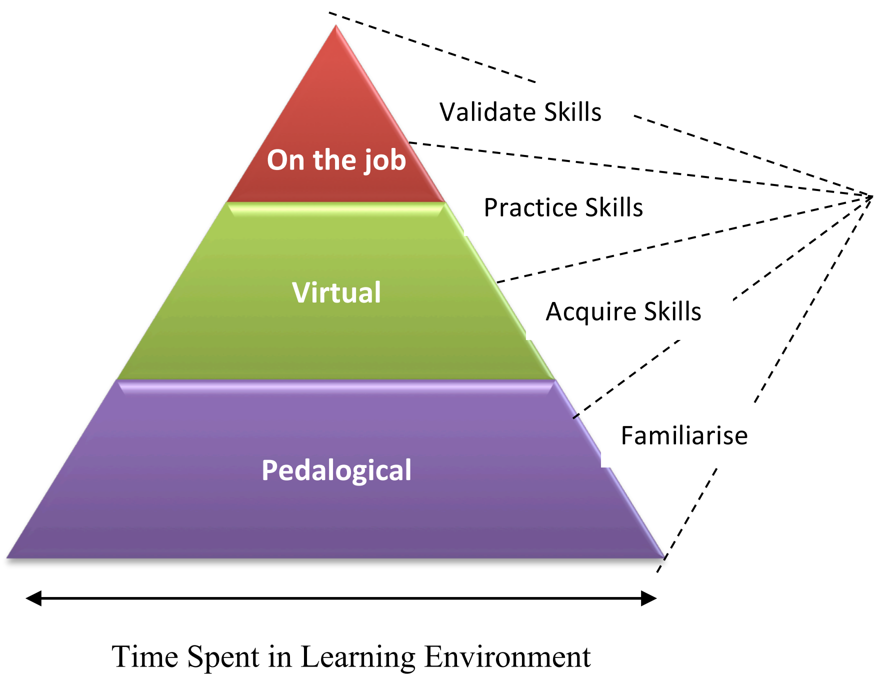

Figure 1. Research Triangle Institute Training Pyramid.

<u>*Benefits of a Virtual Reality Simulator*</u>

Current simulation software for audiology training has a limited human-computer interface (Clyman & Orr 1990; McGaghie 1999), which restricts the student's ability to transfer skills learned to real clients. In recent years, the Parrot Software has been used at universities to assist in training students and assessing them in their puretone-masking test. However, the parrot software is fast becoming outdated with the arrival of new training technology, in the form of Virtual Patients. This is visually apparent when you compare a screenshot of the Parrot software in *Figure 2* to the Virtual Client in *Figure 3*.

Using a Virtual Patient could potentially reduce time and ease the strain on supervisors required for clinical education. This may have the potential impact of larger numbers of students being recruited into the Masters programs for Audiologists and therefore increase the number of audiologists both nationally and internationally. It could also allow the Clinical Educators more time to provide longer and more dedicated supervision to students. Care would have to be taken to not overload or increase strain on Clinical Educators if new students were brought in. As more Master of Audiology students are trained, there is an expectation that universities would attract more PhD students. This would have the end result of enhancing both capability and research productivity, ultimately strengthening the field and the profession of audiology.

Figure 2. Screenshot of Parrot Software

The Audiology Simulator designed for this research study allows students to practice assessment and rehabilitation of hearing disorders with a realistic virtual human. For instance, students of audiology would conduct the standard assessment battery and the human like "Virtual Patient" would provide varying responses, which the students must interpret, and use to plan rehabilitation. *Figure 3* shows what the virtual client looks like based on the University of Florida virtual reality simulation platform that was made available to HIT (Human Interface Technology) Lab NZ for development of the Audiology platform.

Virtual Human

Interacting in a clinical setting

Figure 3: Virtual client presented in a clinical setting

There are some limitations currently in the training of audiology, in particular by the limitation of clinical placement requirements. Students of the MAud degree in New Zealand require a certain level and a minimum of 200 hours of practical training both within the university campus clinical setting and within community settings (University of Canterbury, 2012). Anecdotally, clinical placements outside the tertiary education provider are limited, particularly for first year clinical students, as novice students require a large time-commitment by supervisors.

Audiology departments may be under pressure to meet contracted service requirements and this may place pressure on the ability and willingness of these clinicians to host students, which is an important aspect of an audiologist's training. During the two-year master program for audiology, a large amount of clinical observation and practical learning is required, particularly in settings such as the District Health Board (DHB) Audiology departments. Settings such as this provide a rich learning environment by exposing students to a wide range of pathologies, including some cases that are rare in the general population. Opportunities for placements that provide the full scope of Audiological practice in this way are severely limited.

An Audiology Simulator with Virtual Patients may offer Audiology students a similar experience as would be provided by the exposure during the DHB's placements.

Objective

The introduction of a newborn hearing screening program, combined with an aging population, is concerning given the lack of Audiologists that are trained annually in New Zealand. The potential for universities worldwide to use Virtual Reality and Computer Based Simulations to provide audiology students with basic clinical skills without relying on extensive support from external clinics warrants further investigation as a means of training students more effectively. In particular, it needs to be determined whether audiology students value these simulations as a useful supplement to their clinical training, and whether the use of these simulations translates into measurable improvements in student abilities in real clinical placements. The present study aims to address these needs by determining if a sample of audiology students felt their interactions with Virtual Patients had improved their ability to interact with clients and perform pure tone audiometry and masking techniques.

The aim of this study is to evaluate the Virtual Patients that have been created by HITLAB to be used for the training of Audiology students; compared to traditional training methods in the Master of Audiology program in the area of pure tone audiometry and masking. The simulator allows students to practice assessment and rehabilitation of hearing disorders with a realistic virtual human. The current software programs that are being used are fast becoming outdated and although studies have shown that Virtual Patients have been useful; it has been suggested there needs to be some additional components added that will enhance these programs to make them more reflective of a complete audiological assessment, such as taking a case history and performing otoscopy in addition to assessing the audiometry and masking component. It needs to be examined as to whether this new advanced training tool will assist students in their audiological training and whether they perceive the software to be an effective training and assessment tool for their developing skills.

Research Questions

The first research question is aiming to see whether there is a training effect evident when using the VP when compared to those that have not had access to a Virtual Patient. This will be measured by investigating whether students using a Virtual Patient prior to the first assessment (Group 1) have significantly higher scores in the assessment using a real patient than the students who did not have access to the Virtual Patient prior to the first assessment (Group 2). This will be hereby referred to as the Training Effect.

The second research question that this study aims to investigate is whether the audiometry skills gained by students after using the Virtual Patient are maintained for a time period of four weeks when not using the Virtual Patient. This will be referred to as the Maintenance effect from here on within the study. This will be measured by seeing whether students in Group 1 will have scores of no significant difference to Group 2, showing they maintained their audiometry skills after a time period of not using the Virtual Patient.

The third research question is whether the students themselves find benefit in using the Virtual Patient and whether they find it effective as a training and assessment tool incorporated as part of their clinical training in audiology. This will be assessed by a questionnaire after the students have completed the final post-test and a group discussion the following month, providing time for reflection of the Virtual Patient. A successful Virtual Patient should help the students by providing them with a learning environment, which enabled them to become familiar with the audiometer and protocols; and acquire and practice their skills as outlined in the Research Triangle Institute Training Pyramid.

Method

Participants

Participants included twelve students (3 males and 9 females) enrolled in the first year of the Master of Audiology Program at the University of Canterbury in New Zealand, who participated voluntarily as part of their clinical education and assessment after giving their informed consent. All students came from an undergraduate background and all were naïve to the clinical methods and techniques used in patient puretone audiometric testing. The participants ranged in age from twenty-two years to fifty-five years old and the average age of participants was thirty-three years old. A table describing the participants' characteristics is displayed below.

Table 1. Participant Characteristics.

Age	Sex	Undergraduate Background
23	F	Teaching
38	F	Psychology
23	F	Speech & Language Therapy
22	F	Speech & Language Therapy
25	M	Marketing
55	M	Mathematics
41	F	Nursing
31	M	Nutrition

30	F	Geography
53	F	Teaching
27	F	Psychology
28	F	Speech and Language Therapy

Audiology Simulator

The computer simulation used in this study is referred to as the Audiology Simulator. The Audiology Simulator is used to practice procedural skills, clinical history taking and puretone audiometry, as well as decision-making. This takes the form of the standard audiology range of tests including history taking, pure tone audiometry, otoscopy, and pathology diagnosis for Virtual Patients. The Audiology Simulator is based on a simulation platform originally developed by the University of Florida's Experiences Research Group (VERG). The initial platform had been implemented for research study purposes and was adapted to run as a standalone application. The Audiology Simulator has been implemented in the programming languages C#/C++ using Visual Studio 2010. The application makes use of the open source 3D Library Ogre for graphics, to render the Virtual Patients as well as the room where the consultation takes place within an embedded window.

Virtual Patients

The Audiology Simulator is made up of twenty-five different cases. Each case represents a different type of potential adult client, with a particular diagnosis. These clients are the Virtual Patients. Each Virtual Patient represents a different individual with a different case history and audiological or hearing profile. *Table 2* summarises all the VPs in the simulator and in *Appendix 6* there is the audiogram for each Virtual Patient associated with each of the twenty five cases.

Table 2. Summary of Virtual Patient cases in the Audiology Simulator.

Pathology names
Acoustic neuroma/vestibular schwannoma
Acute otitis media
Atresia
Auditory Neuropathy Spectrum Disorder (ANSD)
Bell's palsy
Benign paroxysmal positional vertigo (BPPV)
Bullous myringitis
Cholesteatoma
Cochlear dead regions
Collapsing ear canal
Cytomegalovirus (CMV)
Endolymphatic hydrops
Foreign body in external meatus
Idiopathic sensorineural hearing loss
Labyrinthitis
Meniere's Disease
Meningitis
Noise Induced Hearing Loss
Non-organic hearing loss (pseudohypacusis)
Ossicular discontinuity
Otitis media with effusion (OME)
Otosclerosis
Ototoxicity induced hearing loss
Perforated tympanic membrane
Retracted tympanic membrane
Wax occlusion

When launching the Audiology Simulator, a student starts with selecting one of the Virtual Patients among the different cases offered. The student is able to select any case, and the cases vary in difficulty in terms of the puretone measurement and the amount of masking required. The application then starts and students have access to the different features of the software, labeled ‘Interview’ ‘Otoscopy’ ‘Tone Test’ and ‘Submit Results’. The students can choose the order of the procedures but would typically start by interviewing the patient, however this was not assessed as part of this study.

Otoscopy

A student can then check the Virtual Patient's ears by looking at two images displayed of eardrums and diagnosing the status of each ear as would normally take place in a diagnostic assessment via otoscopic examination. The purpose of an otoscopic examination is to ensure that the ear canals are free of any obvious problems prior to administering hearing tests or fitting hearing devices. A normal eardrum would have a clear canal, although some cerumen is normal, however cerumen should not occlude more than 50% of the eardrum. The colour of the eardrum should be pearly grey and translucent in appearance. On the Virtual Patient two eardrum pictures are displayed from our collection of pictures retrieved on real patients, which can present additional elements to help identify the appropriate diagnosis.

Puretone Audiometry

The student would then follow with the puretone audiometry procedure. This procedure is about determining the Virtual Patient's hearing thresholds. Hearing thresholds represent a patient's hearing levels, which is the ability to hear sounds properly across the range of frequencies that contain information important for understanding the different phonemes of speech (typically 250 Hz – 8000 Hz). Hearing levels are typically displayed on an audiogram, which are graphs of the hearing level measured in decibels on the y-axis and the frequency range along the x-axis.

To determine hearing thresholds of a Virtual Patient, a student will have to first select an appropriate transducer to use for testing, from the selection of supra-aural headphones, insert earphones and a bone conductor before deciding which ear will be tested first. Then the procedure involves submitting different intensities of sound over the tested frequencies until the

Virtual Patient is able to hear them, if at all. When a tone is presented, the Virtual Patient can either respond to it or not. Once a Virtual Patient responds to a particular tone the student should mark the response level on the virtual audiogram. Masking is configured for the non-test ear depending on the patient's response, if the student considers there could have been conduction from one ear to another during tests. This process is repeated for the entire range of frequencies the student decides to test, for both ears.

Figure 4 shows a screenshot from the simulator illustrating what the interface looks like when the students are conducting puretone audiometry.

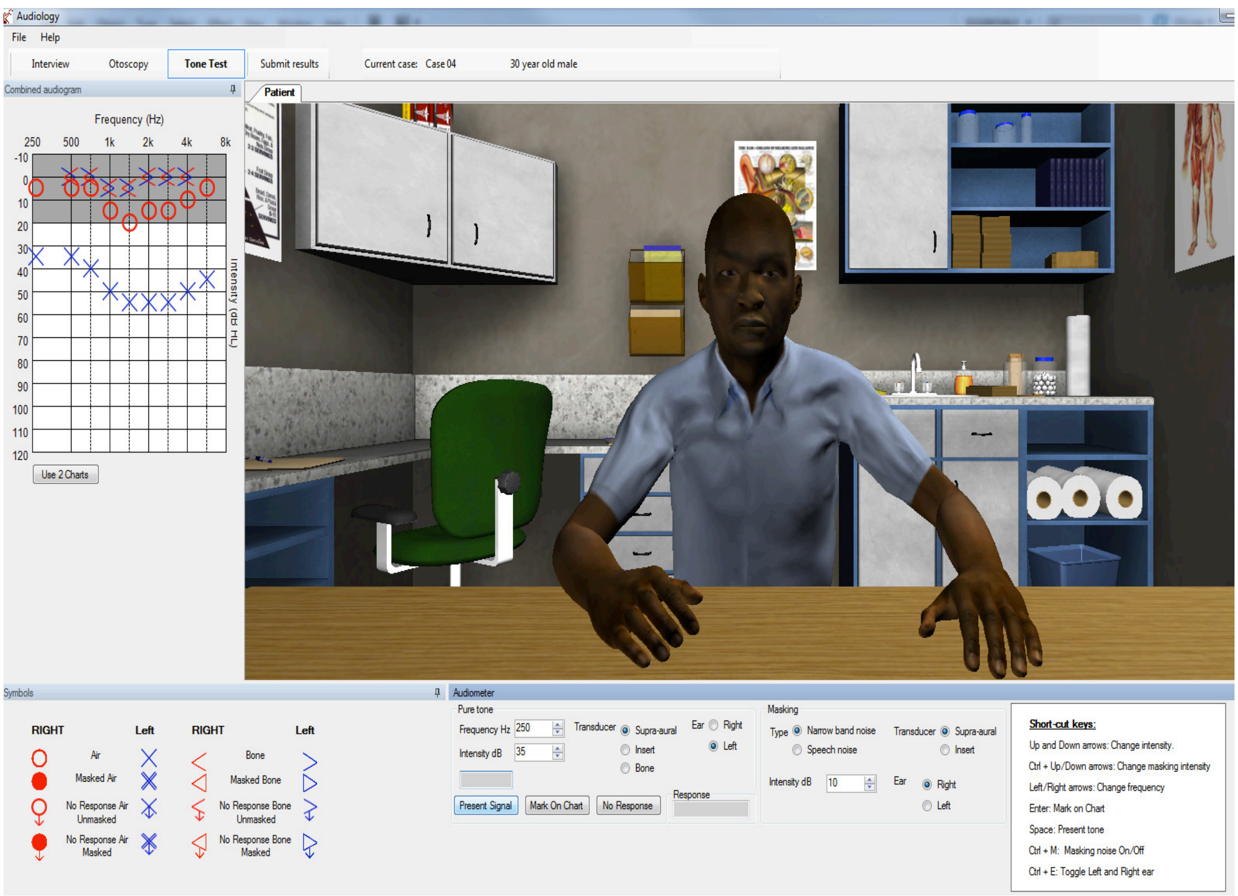

Figure 4. Screenshot of Audiology Simulator interface for puretone audiometry.

Interpretation of Results and Feedback

Following these assessments, the student submits his/her results. The student has to determine the possible pathologies associated with this patient. In addition, a student can choose to pass a comment on his/her diagnosis decision. This information can be recorded and used for assessment. Finally, once the diagnosis is submitted the student will be given feedback in the form of the Virtual Patient's actual audiogram and the correct diagnosis.

Computers

The Audiology Simulator was deployed on a total of seven computers to allow participants to practice during their free time. During their designated training period, participants were able to access the computers and practice on the Audiology Simulator at any time of the week. Basic personal computing systems were used. The simulator was installed on 7 PC computers. The seven computers were between three to four years old, purchased in 2008-2009. The make of the computers was Dell and Cyclone. The processors of the computers were C2D/3000, C2D/2800, C2D2350 and C2D2300. All had memory between 2000 and 4000 RAM.

Preparation for Simulator

In order to prepare the students to use the Audiology Simulator, the students were taught basic audiological techniques of masking and pure tone audiometry. The primary clinical educator of the students taught these skills in the first term of the university year. They provided initial information about the clinical course and introduced the concept of puretone audiometry and masking. They also taught the students to use the HITLAB audiology clinic software. Other basic clinical skills were also introduced, including otoscopy, speech testing and immittance audiometry (tympanometry & acoustic reflexes) through group lecture tutorials over three afternoon sessions each lasting approximately four hours. With each skill that was taught, the students first observed the skills demonstrated and then had an opportunity for hands-on practice.

There were no pre-measures for this assessment, as students had no prior experience or knowledge of puretone audiological testing before it was introduced in their clinical course.

Simulator Experience

The students were assigned to one of two groups based on their grade point average. The six students with the highest grade point average were assigned to Group 1 and the six students with the lowest grade point average were assigned to Group 2. This was to ensure that any differences in skill between the two groups could be explained by looking at the grades of the students. The course's clinical educator introduced both groups to the Audiology Simulator during a four hour masking tutorial.

Following this introduction to the Virtual Patient, Group 1 had two weeks to become familiar with the software and practice their audiometry skills, for example learning which buttons on the keyboard represented the subsequent presenting volume level and changing frequency. This software was made available to the students through computers located in a study room within the university that had 24-hour access. In comparison, Group 2 had the first assessment without having had any exposure to the Virtual Patient, followed by two weeks to become familiar with the Virtual Patient and then followed with a final assessment. The study design is illustrated below in *Figure 6: Study Design*:

Students were instructed to practice on the Virtual Patient in their own time during this training period. It was explained that ideally they were to aim for a minimum of ten hours practice over the two-week period (around an hour per day). Participants were encouraged to ask or get in contact if they had any questions or problems with the software or assessments. A logbook was incorporated into the software to indicate how much time each student spent using the software and practicing their clinical skills.

Group 1

Group 2

Figure 6. Study Design

<u>*Post simulator testing*</u>

A practical test in the style of a mini OSCE was then conducted with both groups to see if there were any significant differences in the students' performance depending on the amount they had been using the Virtual Patient. The test involved the students testing a real life patient with a simulated conductive hearing loss (which had been created by using an earplug hidden under supra-aural headphones to create a flat 30 dB conductive hearing loss). Following this, Group 2 was then exposed to the simulator for two weeks and another practical OSCE test was conducted in the same fashion as the first, (in the second test another conductive loss was simulated by plugging the inside of an insert earphone with blue-tack) assessing all students' ability to integrate the information that they have learnt in the Audiology Simulator and extrapolate it to a real life situation with a real patient with a simulated hearing loss.

This enabled the research to explore two effects of the Virtual Patient. Firstly, a Training Effect which demonstrates the difference between the students puretone audiometry and masking skills before and after use of the Virtual Patient; and secondly a Maintenance Effect which demonstrates if skills gained after using the Virtual Patient are maintained after a certain period of time, which in this study is one month.

Measures

In order to determine whether training was effective, two evaluation tasks were employed. The first task was a real-life diagnostic case. In this case the dependent variables were how the students performed on conducting air and bone conduction audiometry, including masking if necessary, explaining and recording results and the student's confidence in performing the audiometry. The second evaluation task was incorporated in order to evaluate the student experience with the Virtual Patient. The dependent variables were the extent to which they agreed or disagreed with statements that interacting with the Virtual Patient had improved their skills in areas of basic audiometric assessment, including their abilities to obtain accurate unmasked pure-tone thresholds, to obtain masked thresholds, to be confident performing audiometric testing and to learn a new skill. In addition to improving their skills there were also statements exploring the extent to which they rated their level of anxiety about interacting with the Virtual Patient, and the overall usefulness of their interactions with the Virtual Patient as described in more detail in the stimuli section.

An open ended section was available for students to write any further comments they had to describe new skills that they learnt or to provide any feedback or criticism of the Virtual Patient. A copy of this questionnaire can be found in *Appendix 5*. The participating student audiologists who serve as clinical educators for the Virtual Patient would also be invited to give open feedback about the use of the Virtual Patient and on the particular students in this study.

Marking Criteria

A marking schedule for the students' practical assessment was adapted from the marking schedule for the students' clinical course OSCE exam, a copy of this can be found in *Appendix 4*. This marking schedule was used because it reflected skills that the students were assessed on in their usual clinical environment as part of the Master of Audiology course. The main skills that were assessed included:

1) Beginning audiometry correctly, including starting with the correct ear, at an appropriate level based on the information that the students were provided with (for example, that the patient had been having trouble hearing out of their left ear).

2) Conducting air conduction audiometry correctly, including testing in the correct frequency order, a reliability re-test of 1000 Hz and testing half octave frequencies if it was deemed necessary.

3) Using the correct Modified Hughson Westlake method (Katz, 2009) of testing each frequency, where two ascending responses are required to obtain a threshold, and threshold testing is performed in ascending 5 dB steps and descending 10 dB steps

4) Pace, with a maximum of 3 marks being awarded for varied inter-stimulus pace and presentations that last 1-2 seconds. The assessment of the students pace was a product of inter-rater reliability with the patient (actor) also giving the student a rating in addition to the supervisor/marker.

5) Performing bone conduction testing correctly, including correct placement of the bone conductor (on the correct ear and in the correct position), recognising the need for bone conduction at the appropriate frequencies and applying the correct threshold-seeking protocol.

6) Performing masking correctly, including checking if any air or bone conduction masking was needed and then applying the correct plateau masking method to each frequency that requires masking.

7) Explaining the results correctly, including reporting the type of hearing loss (sensorineural/conductive/mixed), and the degree and configuration of the hearing loss.

8) Recording the results correctly on the audiogram, using the correct symbols at the correct levels.

9) Confidence of the student in performing the audiometry. Students were to be penalized for asking the examiner a question that indicated that they were checking for reassurance of the procedure or because they did not know the procedure.

The marks in each of these sections added to a total possible score of 36.

Participant Feedback

A Likert scale style questionnaire based on the one used by Wilson et al (2010) assessed first year students' subjective opinions towards using the Virtual Patient as a training and assessment tool for puretone audiometry and masking skills. Qualitative data was collected from a total of nine questions that were asked. The students were firstly asked to consider their interactions with the Virtual Patient and then secondly to consider the extent to which they agreed or disagreed with each statement.

The first and second statements asked the students if they felt that their ability to obtain unmasked and masked puretone thresholds had improved as a result of working with the Virtual Patient. Masking had been recently been taught to the students and provided a good measure to see if the students felt that the Virtual Patient helped to improve a recently learned skill. The third and fourth statements aimed to determine whether the students' ability to confidently recognise and explain the type and degree of hearing loss had improved as a result of working with the Virtual Patient and also whether their interactions with real patients had improved as a result of working with the Virtual Patient. These are important measures because they aim to determine whether students are able to take the next step and form a diagnosis after completion of testing and whether they are able to draw on the skills that they have been practicing to perform on real patients. The fifth statement was included as a control question because a speech audiometry component had not yet been added to the Virtual Patient. The sixth and seventh statements aimed to determine whether the students felt subjectively that the Virtual Patient had caused them to learn a new skill and whether they found the Virtual Patient useful and it also gave them the opportunity to provide a specific example of skills they had learned. The eighth question aimed to determine whether students felt anxious whilst using the Virtual Patient and the last question asked the students for feedback as to anything that could have been changed or improved with the Virtual Patient in order to assist their learning.

Results

Training Effect

The first research question was concerned with the Training Effect of the Virtual Patient, i.e. whether students using the Virtual Patient scored significantly higher in their practical masking test. The average score in the practical masking test for the group that had received exposure to the Virtual Patient was 80.5% and the average score for the group that had not been exposed to the Virtual Patient was 78.9%. A t-test revealed a P-value of 0.86685, which is not statistically significant.

Figure 7 shows the percentage increase for each individual in the training group (Group 1) from the pre-test to post-test in their mini OSCE assessment.

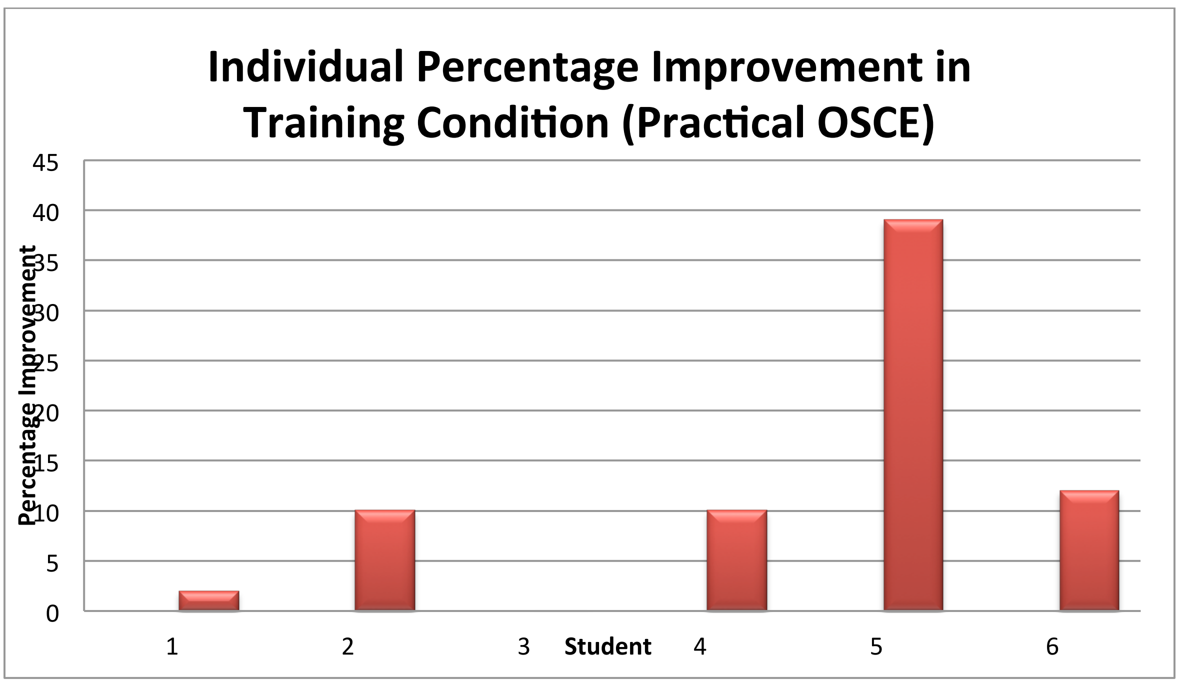

Figure 7. Individual Percentage Improvement from first OSCE to second OSCE in Group 1.

Figure 7 illustrates that after spending time using the Virtual Patient, participants scored at least the same or a higher score in the practical post-test. One of the students had the same score in both conditions, showing no improvement and no deterioration.

Scores for both groups after the practical test were statistically not significant. Scores can be seen in *Table 3*.

Table 3. Scores for Group 1 and Group 2 after the Practical Test

Participant	Group 1	Group 2
1	80.5	63.8
2	76.3	79.1
3	91.6	86.1
4	91.6	79.2
5	87.5	83.3
6	45.8	91.6

The second hypothesis that "Students in Group 1 (using Virtual Patient first) will have significantly higher scores than Group 2 in their post-test after using the Virtual Patient than before using the Virtual Patient. (Training Effect)" must be rejected.

Figure 8 shows the spread of scores in the practical pre & post-test. In the pre-test there is a much wider range of scores from 69% to 85% whereas in the post-test the spread of scores ranges from 79% to 89%, which is statistically significant. As can be seen in *Figure 7*, there was only one participant whose score didn't improve and remained the same in the practical condition; everyone else had an increase ranging from 2-38%.

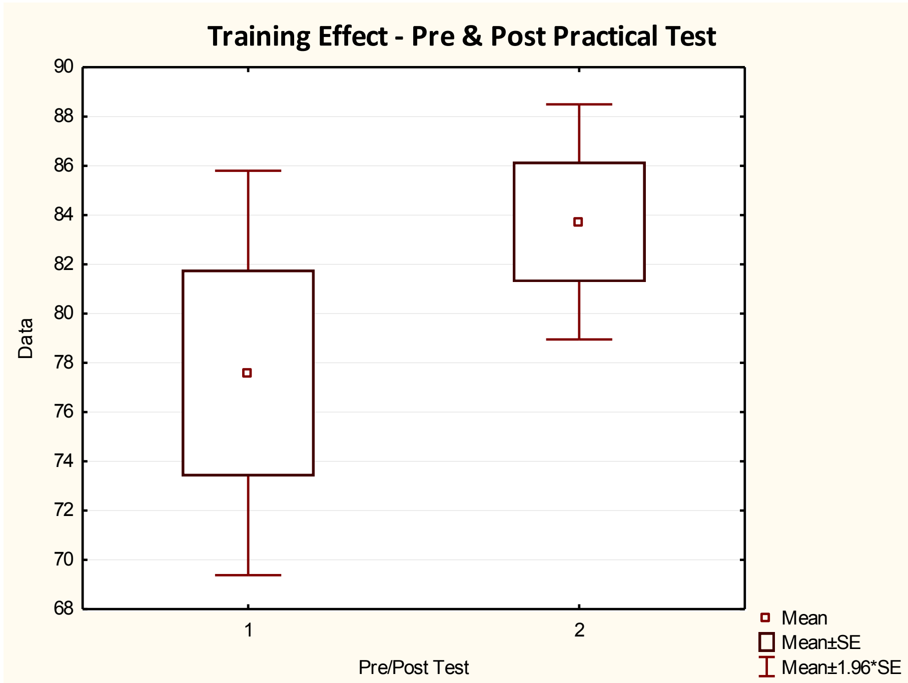

Figure 8: Spread of scores in the Pre and Post Practical Tests in the Training Group

<u>*Maintenance Effect*</u>

The first research question was concerned with the Training Effect of the Virtual Patient, i.e. whether students using the Virtual Patient scored significantly higher in their practical masking test. The majority of students in Group 1 had improved scores after the practical post-test. *Table 4* below shows the pre-test and post-test scores of Group 1 for the practical condition.

Table 4. Group 1's pre-test and post-test scores for the Practical Test.

Participant	Pre test	Post test
1	73.6	80.5
2	84.7	76.3
3	72.2	91.6
4	73.6	91.6
5	79.1	87.5

6	65.2	45.8

For the maintenance effect, it was hypothesised that there would be no significant difference in student's scores from pre-test to post-test. The average score from the pre-test was 74.7% and the average score on the post-test was 78.9%. Whilst this shows a slight overall improvement in score, one third of the group had lower scores on the post-test. A t-test revealed a P-value of 0.53441, which is not statistically significant.

The second hypothesis that "Students in Group 1 will have post-test scores of no significant difference to their pre-test scores, showing they maintained their audiometry skills after a time period of not using the Virtual Patient (Maintenance Effect)" can be accepted.

User Survey and Group Discussion

The questionnaire was answered by all twelve students in the two groups after they had completed their allocated time using the Virtual Patient. The results of the responses to each statement on the questionnaire are shown in the following graphs. As one might expect, due to the short time allocated to using the Virtual Patient (two weeks) and due to some technical difficulties in the use of the program, the students' answers varied in their response to the program.

In the subsequent results, the students' responses to eight statements have been collated in a series of tables. The questionnaire asked participants to consider their interactions with the computer simulation and indicate to what extent they agreed or disagreed with the statements. A Likert scale was used for the first six questions where a score closer to 1 indicated strong agreement and a score closer to 5 indicated strong disagreement. A score of 3 indicated that the participant was unsure and neither agreed or disagreed with the statement.

The first statement of the questionnaire was "*My ability to obtain accurate unmasked pure tone thresholds from a client has improved as a result of working with a computer simulation." Table 5* shows the number of students who agreed with this statement.

Table 5. Participants' response to the statement "My ability to obtain accurate unmasked pure tone thresholds from a patient has improved as a result of working with a computer simulation."

Response	**Frequency**	**Attitude**
Strongly Disagree	0	0% Disagree
Disagree	0	
Unsure	3	25% Neutral
Agree	7	75% Agree
Strongly Agree	2	
Total:	12	

The answers to this statement were mostly positive; 75% of students agreed that using the Virtual Patient had improved their ability to perform basic audiometry obtaining unmasked thresholds and 25% of students were unsure as to whether their skills had improved as a result of using the Virtual Patient.

The second statement of the questionnaire addressed whether the student's ability had improved in obtaining accurate masked puretone thresholds from a patient as a result of working with a computer simulation.

Overwhelmingly the majority of students felt that the Virtual Patient had improved their ability to perform masking in puretone audiometry. Only one student wasn't sure whether the Virtual Patient had improved their ability to obtain unmasked thresholds.

Results for this statement can be seen in *Table 6*.

Table 6. Participants' response to the statement "My ability to obtain accurate masked pure tone thresholds from a patient has improved as a result of working with a computer simulation."

Response	**Frequency**	**Attitude**
Strongly Disagree	0	0% Disagree
Disagree	0	
Unsure	1	8.3% Neutral
Agree	7	91.7% Agree
Strongly Agree	4	
Total:	12	

This is encouraging as the program was planned to replace the outdated Parrot software as a training and assessment tool for assessing the students' masking skills in the Master of Audiology program at the University of Canterbury.

The third statement of the questionnaire addressed whether the student's confidence to recognise and explain the type and degree of hearing loss had improved as a result of working with a computer simulation. *Table 7* illustrates the results from this statement.

Table 7. Participants' response to the statement "My ability to confidently recognise and explain the type and degree of hearing loss from an audiogram has improved as a result of working with a computer simulation."

Response	**Frequency**	**Attitude**
Strongly Disagree	0	25% Disagree
Disagree	3	
Unsure	6	50% Neutral
Agree	3	25% Agree
Strongly Agree	0	
Total:	12	

Most students were unsure as to whether the Virtual Patient improved their ability to confidently recognise and explain the type and degree of hearing loss from an audiogram. Having more of a feedback section incorporated into the Virtual Patient would hopefully help students integrate their audiometry skills with diagnostic skills.

This statement may have been difficult for the students to answer because they were introduced to different pathologies in classes both during and after the use of the simulator.

The fourth statement of the questionnaire asked whether the student's confidence to perform audiometry testing on real patients in the future had improved as a result of working with a computer simulation. *Table 8* illustrates the results from this statement.

Table 8. Participants' response to the statement "My confidence to perform audiometric testing on real patients in the future has increased as a result of working with a computer simulation."

Response	Frequency	Attitude
Strongly Disagree	0	8% Disagree
Disagree	1	
Unsure	1	8% Neutral
Agree	9	84% Agree
Strongly Agree	1	
Total:	12	

Most students felt that their confidence in testing real patients had improved as a result of using the Virtual Patient. This is a positive result as it indicates that students can improve their confidence in diagnostic skills on a simulator prior to seeing real clients in a clinical setting.

The fifth statement of the questionnaire asked whether the student's ability to perform appropriate speech audiometry on a client had improved as a result of working with a computer simulation. *Table 9* illustrates the results from this statement.

This statement was purposefully included as a control; because as the Virtual Patient did not have a section to practice speech audiometry it would be assumed that the Virtual Patient would not improve a student's ability to perform speech audiometry.

As predicted, most students did not feel that their ability to perform speech audiometry was improved as a result of using the Virtual Patient as a training tool.

Table 9. Participants' response to the statement "My ability to perform appropriate speech audiometry on a patient had improved as a result of working with a computer simulation."

Response	**Frequency**	**Attitude**
Strongly Disagree	7	75% Disagree
Disagree	2	
Unsure	1	8% Neutral
Agree	2	17% Agree
Strongly Agree	0	
Total:	12	

There were, however, some students that reported perceived benefit in performing speech audiometry after using the Virtual Patient. This could be because either they felt that in strengthening their audiometry skills, it had the effect of improving their diagnostic skills as a whole, or because they misinterpreted the question.

The sixth statement of the questionnaire asked whether the students learned a new skill as a result of working with a Computer Based Simulation. Table 10 illustrates the results from this statement.

Table 10. Participants' response to the statement "I learned a new skill as a result of working with a Computer Based Simulation."

Response	**Frequency**	**Attitude**
Strongly Disagree	0	25% Disagree

Disagree	3	
Unsure	3	25% Neutral
Agree	6	50% Agree
Strongly Agree	0	
Total:	12	

Overall, students seemed to be unsure as to whether they learned a new skill as a result of working with a computer simulation. This makes sense since clinical educators generally taught the diagnostic skills as an afternoon laboratory, and the Virtual Patient would then serve to reinforce these skills at a later date rather than teaching new skills. The second part of this statement asked the students to provide a specific example if they desired. The following are examples of new skills learnt as a result of working with the Virtual Patient:

- "The procedure of masking has become clearer and recognising when masking is needed"
- "Increased efficiency in my testing, in particular calculating masking levels"
- "Better handling of an audiometer"
- "Before I used to forget to test inter-octave frequencies but now I know to do this when there is a 20 dB gap or more between thresholds"
- "Developing a system/series of steps that I can follow to be more efficient"
- "Patience; but also that clients may not be as reliable as the Virtual Patient"

In the next statement the Likert scale changes from one of agreement to usefulness, where a higher score indicates more usefulness in the following way: Where 0 indicated not useful at all and 4 indicated extremely useful. *Table 11* indicates the general attitude towards the usefulness of the Virtual Patient.

Table 11. Participants' response to the statement "How useful interacting with the computer simulation was overall?"

Response	**Frequency**	**Attitude**
Not Useful	0	25% Not very useful
A little Useful	3	
Moderately Useful	8	67% Neutral
Very Useful	1	8% Very Useful
Extremely Useful	0	
Total:	12	

Results show that students on the whole found the Virtual Patient to be moderately useful. This is to be expected, as there is a lot of room for improvement and other areas such as speech audiometry and immittance audiometry where the Virtual Patient can be expanded.

The last statement has a different scale again where a higher score represents more anxiety as follows: Where 0 indicates no anxiety at all and 5 indicates that the participant felt extremely anxious. *Table 12* indicates the general attitude towards the anxiety level of student whilst using the Virtual Patient.

Table 12. Participants' response to the statement "How anxious you were overall during the interactions with the computer simulation?"

Response	Frequency	Attitude
Not Anxious	5	92% Not very anxious
A little Anxious	6	
Moderately Anxious	1	8% Neutral
Very Anxious	0	0% Very anxious
Extremely Anxious	0	
Total:	12	

These results show that students experienced little anxiety during their interactions with the Audiology Simulator.

The last part of the questionnaire asked the students whether there was anything in the computer simulation that could be changed to assist their learning. A group discussion was also held with eleven out of the twelve students attending and giving their feedback on the usefulness and potential of the Virtual Patient as an educational training and assessment tool for audiology.

The major reported criticism was the repeated system crashing of the Virtual Patient where the program would freeze halfway through a case the student was working on and they would lose their work after having restarted the program. Most students admitted that after this had occurred a number of times, they felt understandably unmotivated to continue to pursue practicing their audiometry skills using the Virtual Patient.

However, the majority of students expressed agreement with the potential of the Virtual Patient as a training tool and its use in future examinations. Most of the students reported that interacting with the computer simulation was “Moderately Useful”. The majority of students were not anxious during interactions with the Virtual Patient.

Suggestions of how the computer simulation could be changed in order to assist the students learning included:

- “Addressing the crashing issues”
- “Feedback in the program on what was wrong with their answer at the end of a session”
- “Showing the inter-octave frequencies that needed to be masked (for example, 750 Hz, 1500 Hz and 3000 Hz alongside the standard frequencies”
- “A prompt on the VP saying “do you need to mask?” or a pop up box or checklist similar to what the student had when she was undergoing her nursing training”
- “A closer match in the interface of the Virtual Patient audiometer to the audiometer used at the University for ease of learning for students”
- “More variable responses in response timing or false positives/false negative responses (like a client in real life)”
- “Reference tables in the program for masking values for IAA and OE”
- “The option to print out your results”

Discussion

At present, the ability to train Audiology students was limited due to the time involved to educate students in practical methods and the limitations of possible placements for clinical experience. This was seen as a concern due to the potential need for more trained Audiologists, given the implementation of a Newborn Hearing Screening Program and the effect of an aging population in New Zealand. The potential to train students using a computer-based system is currently limited due to technological limitations, and therefore the Audiology Simulator was seen as a possible solution to this issue. A number of research questions were proposed to evaluate various elements of audiological training using a Virtual Patient. Each outcome is discussed below. Following the discussion, the clinical implications are discussed.

Research Question 1) To determine whether there is a training effect evident when using the Virtual Patient when compared to those that have not had access to a Virtual Patient.

This question was looking at determining whether using a Virtual Patient could be used to train Audiology students as an alternative method to hands on clinical training with a tutor. This was suggested, as it would mean that students could learn, improve their learning, or conduct self-directed learning, and have improved scores on further assessments after having access to a Virtual Patient to practice and enhance their skills. This was measured by investigating whether students using a Virtual Patient prior to the first assessment (Group 1) had significantly higher scores in the assessment using a real patient compared to the students who did not have access to the Virtual Patient prior to the first assessment (Group 2). This was referred to as the Training Effect. Results from the study indicated that there was not a significant difference between the groups, so the first research question was rejected.

One possible reason for the rejection of the first hypothesis is that the students did not spend sufficient time using the Virtual Patient to affect their performance. Students reported back through the group discussion that they only spent the minimum required time period of two hours per week with the Virtual Patient. Future studies should require more hours to be spent with the Virtual Patient, possibly supervised hours, so that students were more likely to attend during a specific time period and because there would be someone available for their questions or in the case of the program crashing. The students provided a number of reasons for not spending more time with the Virtual Patient. These included the significant course load associated with the Master of Audiology program. The other reason the students cited for not spending more time using the Virtual Patient was the fact that the simulator wasn't reliable and it would at times crash. Previous research indicated that students like Computer Based Simulation programs because computer based education has the opportunity to cater to the different learning styles of individuals by being multimodal in its teaching style. Information can be transferred to the student by visual, aural, written and kinesthetic or interactive methods making it suitable to a range of individuals with different learning styles. (Cook, D. A., Levinson, A. J., Garside, S., Dupras, D. M., Erwin, P. J. & Montori, V. M, 2008). However, not all students embrace Computer Based Simulation as an educational tool for learning, particularly those that are not familiar with computers. One student in this study disliked the Audiology Simulator because they did not feel comfortable with the level of technology that was demonstrated in using a Virtual Patient. This is consistent with previous research from Shaw & Marlow, (1999) who suggested that a proper introduction to the computer program could possibly further overcome this barrier and enhance the individuals' overall perception of the computer program.

Furthermore, the students also indicated that they were reluctant to come into the university room where the computers were located with the Virtual Patient after hours because of the fear of earthquakes, which had occurred in the Canterbury region within the past year. In the future, installing the Virtual Patient on the students' own personal computers would alleviate this problem and make the program more accessible to all students at any time they were wanting to use it. This was not possible during this study as updates were continually being made to the software and this was more easily coordinated having all of the computers with the Virtual Patient located in one place within the university.

A second possibility for rejection of the first research question could be that the students were also concurrently receiving clinical training in audiometry and masking through their weekly practical experiences at the university clinic. It is possible that this training was, in itself, sufficient practice for their masking skills. Therefore, the Virtual Patient was not a training tool as such but rather a tool that increased their confidence in masking (as cited by the students). It could be suggested that the students' knowledge of masking was already relatively sound at the time of testing. If that was the case, then if the test was taken at a time closer to when the students had just started learning about masking, and therefore had a limited knowledge base on the subject, then those students who had spent more time practicing with the Virtual Patient would have had higher scores. However, it is hard to draw many conclusions as the students struggled to spend the suggested 2 hours per week using the Virtual Patient. Previous research indicated that Computer Based Simulation as an educational and assessment tool is appropriate in many health professions due to the time and resource constraints faced by supervisor to student ratios (Baillie et al, 2000) but that time constraints remain one of the main barriers to instructional simulations (Baillie et al, 2000). This is consistent with the current study where the majority of students found the Audiology Simulator overall to be 'moderately useful' but then did not feel that they had adequate time in their schedules to make use of it due to their heavy course load.

Research Question 2): To investigate whether the audiometry skills gained by students after using the Virtual Patient are maintained for a time period of four weeks when not using the Virtual Patient.

Results from the present study indicated that students in Group 1 (who used the Virtual Patient prior to the first clinical assessment) were able to maintain their clinical skills in pure tone audiometry and masking for a period of weeks after discontinuing the use of a Virtual Patient. The results showed a significant effect. Therefore, the results from the present study provide support for this research question.

This is a promising result in that the effect of training from the Virtual Patient was maintained after a period of time and the student's scores did not decrease. Previous research has shown that Computer Based Simulation programs help to retain knowledge as they improve learning and practice (Baillie et al, 2000; Mangan, 2003; Kneebone, 2000; Boyd & Jackson, 2004; Turkle, 2004) by catering to different learning styles in its multi-modality. It also engages students by allowing them to participate in testing rather than simply observing and since it is a computer simulation the students are less afraid to make mistakes and this in turn leads to it being able to motivate students (Reigeluth et al 1989; Baillie et al, 2000; Yarger et al, 2003; Mitchell, 2004) to practice their clinical skills. This research demonstrated that the Audiology Simulator in question acted as a supplementary training tool that was available to students to further enrich their clinical training that was taking place each week and this improved their learning and practice of puretone audiometry and masking skills, consistent with previous research (Baillie et al, 2000; Mangan, 2003; Kneebone, 2000; Boyd & Jackson, 2004; Turkle, 2004).

There is a possibility, however, that the Virtual Patient cannot take full responsibility for this pleasing result. This may be due to the issue that the students were also attending practical clinic sessions on a weekly basis where they were given the opportunity to practice their audiometry and masking skills. There is also the possibility that the students may have been undertaking self-study or practice sessions by themselves or with peers. Nonetheless, one may make the assumption that the Virtual Patient contributed to this learning and to the maintenance of their clinical skills.

Results from the discussion with the students some time after using the Audiology Simulator indicated that the students overall found the Virtual Patient to be "moderately useful". This suggests that even if the newly introduced masking and audiometry skills weren't actually maintained exclusively by the Audiology Simulator, they were at least developed and reinforced when the students had time to use it.

Research Question 3) To determine whether the students themselves found benefit in using the Virtual Patient and whether they find it effective as a training and assessment tool incorporated as part of their clinical training in audiology. This was assessed by a questionnaire after the students have completed the final post-test and a group discussion the following month after providing time for reflection of the Virtual Patient.

Results from the present study were consistent with this research question and found positive responses from the students regarding the use of the Virtual Patient. A successful Virtual Patient should help the students by providing them with a learning environment, which enabled them to become familiar with the audiometer and protocols; and acquire and practice their skills as outlined in the Research Triangle Institute Training Pyramid (Hubal et al, 2003). Using this model, the Audiology Simulator provided the students with a learning environment, which in turn enabled them to become familiar with protocols and procedures, which in turn enabled them to demonstrate sound clinical skills that they had acquired during the OSCE style assessment. The results from the study were consistent with those themes and illustrated that the students found the Audiology Simulator to be an effective training tool with all students indicating that they found it 'moderately useful or extremely useful overall' and therefore the third research question is supported.

The questionnaire provided useful feedback in terms of how helpful the students found the Virtual Patient in different areas of diagnostic skills. The students were forthcoming in terms of the ways in which it could be improved or modified to assist their learning. Additional themes which could be included in a future questionnaire include the extent to which they agreed or disagreed with statements about the following aspects of their interactions with the Virtual Patient: the realism of the case content, the usefulness of the feedback, their level of preparation, the amount of background information they were given, the training they were given and the reinforcement of skills learned in lectures.

Clinical Implications

The present study was carried out in response to a clinical suggestion that an Audiology Simulator could be used to help train Master of Audiology students at the University of Canterbury. Past studies have shown that two of the main barriers or limitations to the use of instructional simulations cited are: **1)** capital costs and time constraints (Baillie et al, 2000) and **2)** technical barriers, in particular teachers with limited computer skills or knowledge to pass on to their students (Baillie et al, 2000). In the present study, students cited both of these things as major barriers to using the Virtual Patient more. The first barrier that they cited was that they were too busy with their course load to use the Virtual Patient on a regular basis. Secondly, students cited that there were often technical difficulties with the simulator, including frequent crashing, which limited the use of the Virtual Patient as a training tool. We can conclude that the present study is consistent with previous research findings on this matter. It is important to note that the Virtual Patient that was being evaluated in this research was a pilot test of the software and the majority of the technical issues that are mentioned in the students' feedback have since been resolved. In future research and training using the Virtual Patient, it may be beneficial to have a compulsory time period on a regular basis where students have a chance to use the simulator and go through cases in a supervised environment where there is an educator close by to answer any questions and to encourage clinical thinking and reasoning when the students are interpreting different cases.

There are several themes mentioned which have emerged from past literature when looking at the potential for educational technology to improve teaching and learning. This was that it should include the following; Visualisation, Authentic Engagement, Quality and Quantity of Practice and Feedback, Interaction and Collaboration and Reflection (Rochelle et al, 2000; West & Graham, 2005). These themes were addressed in an informal open group discussion held with eleven out of the twelve students after all of the practical assessments had taken place with the Virtual Patient. The themes will be discussed in terms of the potential this computer-based simulation has in effective learning for audiology students.

Visualisation

Many of the students reported that an advantage of the Virtual Patient was that it helped them to visualise specific hearing losses by the wide variety of hearing conditions that were able to be portrayed. This meant that the students could practice their diagnostic and clinical skills with different hearing losses in the Virtual Patient that they otherwise may not have been exposed to during their normal clinical practice with real clients. Therefore this is consistent with previous research by Alinier, Hunt, Gordon & Harwood (2006) who found that Computer Based Simulation training was a useful technique that allowed students to practice in a safe and controlled environment whilst dealing with a variety of different cases that they would otherwise not normally see. They noted that this type of training had the potential to be very valuable in its ability to equip students with a minimum of technical and non-technical skills before they are expected to use them with real patients in the clinical setting.

In an education setting, this would allow the clinical educator to connect their computer to a projector and work through cases with the class together, allowing students to see the frequency and decibel level change as they perform audiometry, whilst also enabling them to visualise how masking worked. One student commented that working through an audiogram in this way was much more useful than if they were just shown pictures of completed audiograms for a specific hearing loss. Therefore, the Audiology Simulator covered the need for visualization in a learning experience.

Authentic Engagement

Authentic Engagement is often a concern when it comes to Computer Based Simulations as you want the student to be able to extrapolate what they are learning to a real world environment (Clyman & Orr, 1990; McGaghie, 1999). Although the Virtual Patient did not have a realistic looking audiometer for the students to practice with, it did provide authentic cases to practice their skills on. Before the implementation of the simulation, students would attempt to imitate hearing loss by wearing earplugs (to simulate a hearing loss) when they were being tested. This practice proved less than satisfactory as it limited the students to practicing testing with a conductive hearing loss. However, with the Audiology Simulator the student could select cases for practice that were of varying hearing losses and level of difficulty for the student. Therefore for the purposes of this study, the Audiology Simulator was designed to allow students to extrapolate what they had learned to a real world environment when seeing real patients so that the concerns raised by previous research by Clyman & Orr (1990) and McGaghie (1999) was addressed. One way in which the Virtual Patient could be improved in the future would be to have an authentic or realistic looking audiometer similar to what the student would be familiar with.

Quality and Quantity of Practice and Feedback

Research has shown that quality and quantity of practice and feedback is important because feedback helps with reflexive learning (Clyman & Orr 1990; McGaghie 1999) where the student learns to correct their mistakes whilst completing the task at hand. The Audiology Simulator also facilitates a higher quantity of practice opportunities (and therefore feedback opportunities) as the simulator can be used at anytime on any one of the university's computers. When the students practiced on the audiometers in the clinic, the number of machines available and the higher number of students meant that there were a limited number of practice opportunities. In the future when the software is ready and not requiring regular updates, it would be desirable for students to be able to also practice at home on their own personal computers as well. A criticism of the Audiology Simulator was that it should provide more feedback as to where exactly the students had gone wrong and specific areas for them to work on. Even if a feedback feature fails to be incorporated into the Audiology Simulator, there is still the opportunity for the clinical educators of the program to provide students with a variety of cases then when they are completed, easily assess their results. Therefore the Audiology

Simulator does not currently provide explicit feedback at the moment but provides opportunities for reflexive learning as the student may learn from their past mistakes as described in previous research by (Clyman & Orr 1990; McGaghie 1999).

Interaction and Collaboration

Previous studies indicated that it is important to collaborate as a class to improve learning (Rochelle et al, 2000; West & Graham, 2005). Working through cases as a class using a Virtual Patient up on a projector screen allows the class to interact and together decide on a clinical plan for each particular case. This makes the Audiology Simulator an invaluable training tool for teaching a large number of students at one time. It would be much harder to collaborate in this way if the situation was that there were more than two or three students crowded around a single audiometer with the clinical educator. Therefore, the Audiology Simulator provided this requirement of interaction and collaboration. However, typical use of a Virtual Patient does not promote interaction and collaboration (as it is used by an individual rather than a large group). It should be noted that on a number of occasions it was observed that students would pair up and go together to practice using the Audiology Simulator in their own time outside of class. This illustrated the potential of the Audiology Simulator to be used in a collaborative sense; students could be encouraged after they had each worked through the same cases to then discuss their results and any concerns they might have had.

Reflection

Reflection on learning has been shown in previous studies to provide further insight (Rochelle et al, 2000; West & Graham, 2005). In the current research, the study of the effectiveness of the Audiology Simulator as a training tool promoted a lot of reflection for the students and their learning. Through the questionnaire and the group discussion, many of the students commented that it was helpful to think about their learning and be actively involved through this study in the specific ways it could be improved.

The clinical educator noted that when the Audiology Simulator was first introduced, students questions were focused around the mechanics of what he was doing (for example the level to put masking in and the values for occlusion effect and interaural attenuation) and after using the Audiology Simulator, the questions changed to being concerned more with why he was doing what he was doing and what the results meant. This is consistent with research by Reed, Oughton, Ayersman, Ervin and Giessler (2000) that shows that students reflect more independently on learned information once they have learnt basic skills.

Since the use of the Audiology Simulator has the potential to provide more opportunity to practice with more authentic cases in the form of Virtual Patients; with some more encouragement it could offer even more opportunities for reflection.

Limitations

A limitation of the Audiology Simulator used in this study was that the designer of the program did not have an audiological or speech science background. As a result, there may have been less revisions to the Audiology Simulator if the programmer had understood the theory behind certain tests and rules of audiometric testing involving which transducers are being used and how this would effect the interaural attenuation values or the occlusion effect when calculating masking levels.

A second limitation to this study, as discussed previously, was that all students mentioned that the main reason that they did not spend more time using the Audiology Simulator was that the program would sometimes freeze for no apparent reason due to bugs in the program during testing. This then caused the student to lose all the work they had done on that particular case and require that they start again or insufficient operating system requirements of the computers that were being used to run the Audiology Simulator. This, in turn, reduced their enthusiasm to practice using the Audiology Simulator.

A further limitation was that the time-log that was meant to record the exact amount of each student spent using the Audiology Simulator was invalid due to continual upgrades to the software and due to different computers being used. The fact that some students decided to work in pairs would have also made the time log difficult to calculate. This is another reason why it would be better for students to have a scheduled time to use the Audiology Simulator under a supervisor and receive feedback.

There were also some environmental limitations that impacted the timing of the study. Students were unable to access the Audiology Simulator for the first week after it was introduced due to significant earthquake aftershocks happening in the region causing the university to close on a number of occasions. This could be alleviated in the future by allowing the students to have their own personal copy of the Audiology Simulator so that they were able to use the training tool wherever and whenever they wanted to.

Further research could look at including a speech audiometry component may be added to the program, along with tympanometry and reflexes. By having a larger test battery, along with a greater number of possible results to interpret, this would provide a more holistic and realistic case allowing the student to integrate their clinical skills whilst also enabling the student to target their practice on any particular area they felt they needed to spend more time in.

Students indicated that they wanted feedback to be incorporated into the program so that they knew where they had gone wrong and what they should have done rather than an overall grade that didn’t point out in which section they had lost marks. This could either be incorporated into the program or the clinical educator could provide feedback to the student after looking over the cases.

In the future, using a Learning Styles Questionnaire such as the VARK would assist educators in determining the learning style of each student and of the class as a whole. In this way they could modify their teaching and lecture material to be of best use to the students.

Conclusion

The present study indicates that computer based simulation programs like the Audiology Simulator are able to present and simulate realistic hearing losses to an acceptable level of complexity for students studying in the field of audiology that helps improve their understanding of technical skills to better skill them in clinical and diagnostic skills. This in turn will support the possibility of using the Audiology Simulator to train and develop student audiologists, which in turn may help increase the number of people who can study in this profession at any one time. The benefit of this will be a greater number of trained Audiologists to cover staffing requirements that are bought on with the implementation of a nation-wide newborn hearing screening program and the effect of an aging population.

All students actively volunteered to participate and completed the whole session of assessment using the Audiology Simulator indicates that in general they were positive about the use of virtual training and simulation of a patient for assessment purposes.

This study showed that the Audiology Simulator can be a useful and complementary training tool for components of audiological clinical competence, such as masking, however it is only a complement to traditional training methods and it cannot replace the learning outcomes that occur after the interaction with real life clinic patients. With further development and enhancements, this research supports the further development of the Audiology Simulator as a training tool for student Audiologists.

Glossary

Abbreviation	Definition
AS	*Audiology Simulator*
DHB	*District Health Board*
HIT Lab	*Human Interface Technology Lab*
MAud	*Master of Audiology Degree*
NBHS	*Newborn Hearing Screening Program*
OSCE	*Objective Structured Clinical Examination*
SRT	*Speech Reception Threshold*
VP	*Virtual Patient*

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Appendices

Appendix 1: Invitation letter to students

Hello,

We are offering you an opportunity to participate in research being conducted by researchers from the Department of Communication Disorders and the Human Interface Technology Laboratory. The project is developing a virtual client simulator to be used in the clinical audiology course to supplement traditional means of teaching.

You can find more information about what taking part in the research involves in the information sheet you have been given.

Thank you for your time and consideration. It is only with the generous help of people like you that we can develop our project.

Yours sincerely,

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Appendix 2: Information Sheet

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Information Sheet

Interactions with Virtual Patients in Clinical Simulation

You are invited to take part in this study as part of a project aiming to develop a 'virtual client simulator' for use as training software in the Clinical Audiology course.

The aim of this study is to find out if using a virtual client simulator in addition to the Clinical Audiology course's traditional teachings could help you to refine your skills further prior to meeting real patients.

Who are the researchers?

A team of researchers from the Department of Communication Disorders and the Human Interface Technology laboratory is conducting this study.

The researchers in the team from the Communication Disorders department are: Libby Sanderson, Sarah Howland, Jonny Grady, and Dr Catherine Moran.

The HIT Lab researchers are Alexandre Heitz and Dr Andreas Duenser.

This study also forms part of Alexandre Heitz's PhD, and Libby Sanderson and Sarah Howland's Masters thesis.

How were participants selected for this study?

First year students in the clinical audiology course have been invited to take part as they are the target audience for the virtual client simulator.

What will the research involve?

We are asking you to practice seeing virtual clients on the simulator over a two week period of the course and to take part in two assessments over the next eight weeks.

What are the benefits of the study?

This study will allow you to receive additional training in clinical audiology as well as give you another opportunity to practice your skills before working with real clients.

This study will also provide information that will help in developing more realistic virtual clients and to refine our simulator before further use for the clinical audiology course.

Do I have to take part?

No, your participation is entirely voluntary (your choice). If you choose not to take part this will not affect your academic progress. We hope that you will participate because we need to obtain as many responses as possible to ensure that the virtual client simulator grows as realistic as we can make it for you to use.

You may withdraw at any time. However, taking part in all activities will provide the best information for the study.

Will my taking part in this study be kept confidential?

Yes, the following steps have been taken to ensure the confidentiality of the research.
(1) Anonymity will be maintained using aliases.
(2) Access to the data is limited to the researchers named above.
(3) The data will be stored securely at the University of Canterbury for five years following completion of the project and then the data will be destroyed.

What will happen to the results of this study?

The results of this study will allow us to refine the virtual client simulator. The results of this study will be reported as part of the project in journal publications, conference presentations, and on the internet.

It will also be reported as part of Alexandre Heitz's PhD thesis, and Libby Sanderson and Sarah Howland's Master thesis.

If you would like a copy of the results of this study please contact Alexandre Heitz, Libby Sanderson, or Sarah Howland.

Who has approved this study?

This study has been reviewed and approved by the Human and Interface Technology laboratory (HIT Lab NZ), and the University of Canterbury Human Ethics Committee.

Please contact Alexandre Heitz, Libby Sanderson or Sarah Howland if you have further questions.

Appendix 3: Consent form

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Consent Form

• I have read and accept my rights, and am happy to take part in this project.

• I understand that the data resulting from this study will be used by Alexandre Heitz in his doctoral research, and by Libby Sanderson and Sarah Howland in their master's thesis.

• I understand that the data might appear in publications related to the Virtual Patient simulator project.

• I understand that the data will be held securely and kept for a minimum period of 5 years following completion of the project before being destroyed.

• I understand that my name will not be used in any presentations or reports, unless I specifically request it.

• I understand that I am able to withdraw at any time from this research.

Name: ____

Signed: ____

Date: ____

Appendix 4: Copy of the Practical Assessment Marking Schedule

Practical Assessment

Students do not need to perform otoscopy, give instructions to client or choose correct transducers as the client will be sitting with transducers correctly placed (supra-aural) ready for audiometry to be performed. There will be a foam earplug in the left ear of the client to produce a conductive loss. Information given to student: Client concerned about left ear - harder to hear with recently.

1. ***Begin Audiometry (2)*** with better hearing ear (right)? /1
   with appropriate level (30-50 dB HL)? /1

2. ***AC Frequency Order (3)***
   1kHz†2kHz †4kHz†8kHz†500Hz†250Hz /1
   Doing ½ octave frequencies if ≥20dB difference between octave thresholds /1
   Recheck of 1kHz /1

3. Use correct ***Mod. Hughson Westlake*** *method* (-½ each mistake) ***(5)*** /5

4. ***Pace (3)***
   3 – for varied inter-stimulus pace & 1-2s presentations
   2 – for some lack of variation or too short/long presentations
   1 – for little variation and too short/long presentations /3

5. ***Bone Conduction (5)***
   Correct bone conductor placement (ear & position) /1
   Recognising need for BC at appropriate frequencies (-½ each mistake) /2
   Apply correct threshold-seeking protocol (-½ each mistake) /2

6. ***Masking (8)***
   Checking need for any BC masking (-½ each mistake) /2
   Checking need for any AC masking (-½ each mistake) /2
   Apply correct Plateau method to each frequency that needs it
   4 marks total (-1 mark each mistake) /4

7. ***Explaining Results (3)***
   Type of loss (sensorineural/conductive/mixed) /1
   Degree of loss (mild/moderate/severe) /1
   Configuration of loss (sloping/rising/flat/cookie-bite/etc.) /1

8. ***Recording Results (4)***
   1 mark for each correctly recorded AC ear & BC ear
   (2 marks for AC; 1 for unmasked BC; 1 for Masked BC) /4

9. ***Confidence (3)***
   3 – Perform audiometry comfortably and confidently
   2 – Do they check once or twice for reassurance?
   1 – Do they check multiple times for reassurance of procedure? /3

Total /36

Appendix 5: Copy of the subjective questionnaire

Consider your interactions with the computer simulation. Please indicate to what extent you agree/disagree with the following statements:

1 – *Strongly Disagree,* 2 – *Disagree*, 3 – *Unsure*, 4 – *Agree,* 5 – *Strongly Agree*

1. My ability to obtain accurate unmasked pure tone thresholds from a client has improved as a result of working with a computer simulation.

   1 2 3 4 5
2. My ability to obtain accurate masked pure tone thresholds from a client has improved as a result of working with a computer simulation.

   1 2 3 4 5
3. My ability to confidently recognise and explain the type and degree of hearing loss from an audiogram has improved as a result of working with a computer simulation.

   1 2 3 4 5
4. My confidence to perform audiometric testing on real clients in the future has increased as a result of working with a computer simulation.

   1 2 3 4 5
5. My ability to perform appropriate speech audiometry on a client has improved as a result of working with a computer simulation.

   1 2 3 4 5
6. I learned a new skill as a result of working with a computer simulation. (Please provide a specific example in the space below if desired)

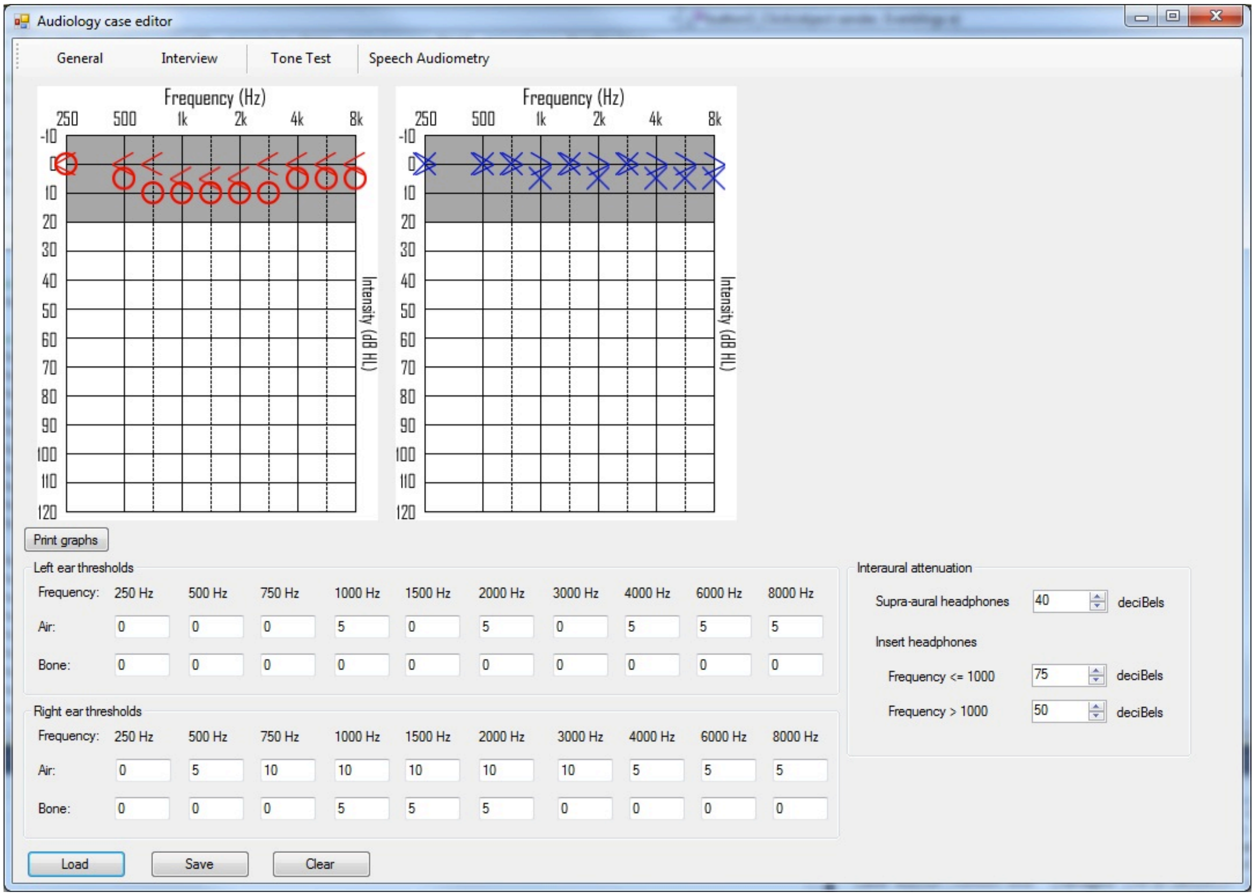
   1 2 3 4 5

7. Please indicate (circle) on the following scale how useful interacting with the computer simulation was overall:

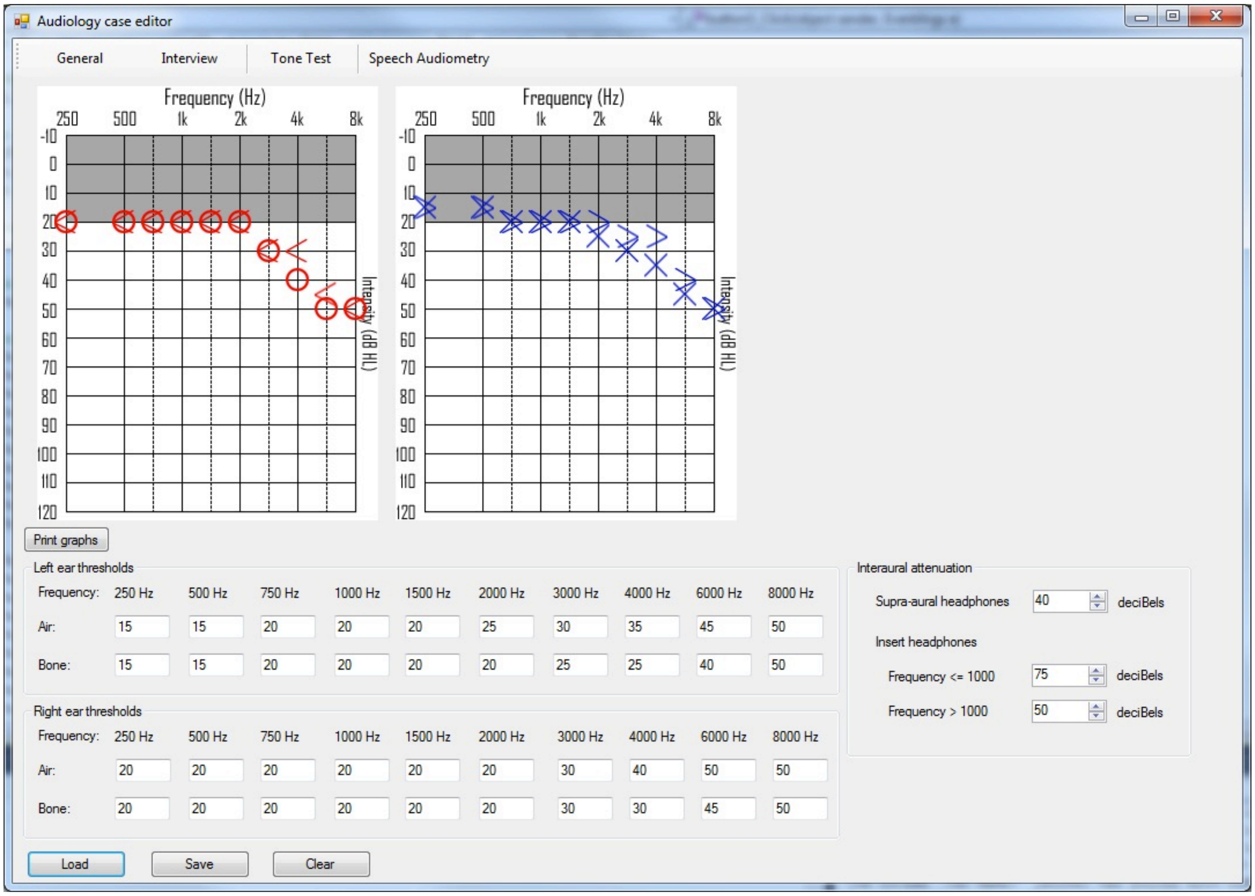
   0 – *Not Useful*, 1 – *A little useful*, 2 – *Moderately Useful,* 3 – *Very Useful,* 4 – *Extremely Useful*
8. Please indicate (circle) on the following scale how anxious you were overall during the interactions with the computer simulation:

   0 – *Not anxious*, 1 – *A little anxious*, 2 – *Moderately anxious,* 3 – *Very anxious,* 4 – *Extremely anxious*
9. Was there anything that could be changed with the computer simulation to assist in your learning? (Please provide a specific example in the space below)

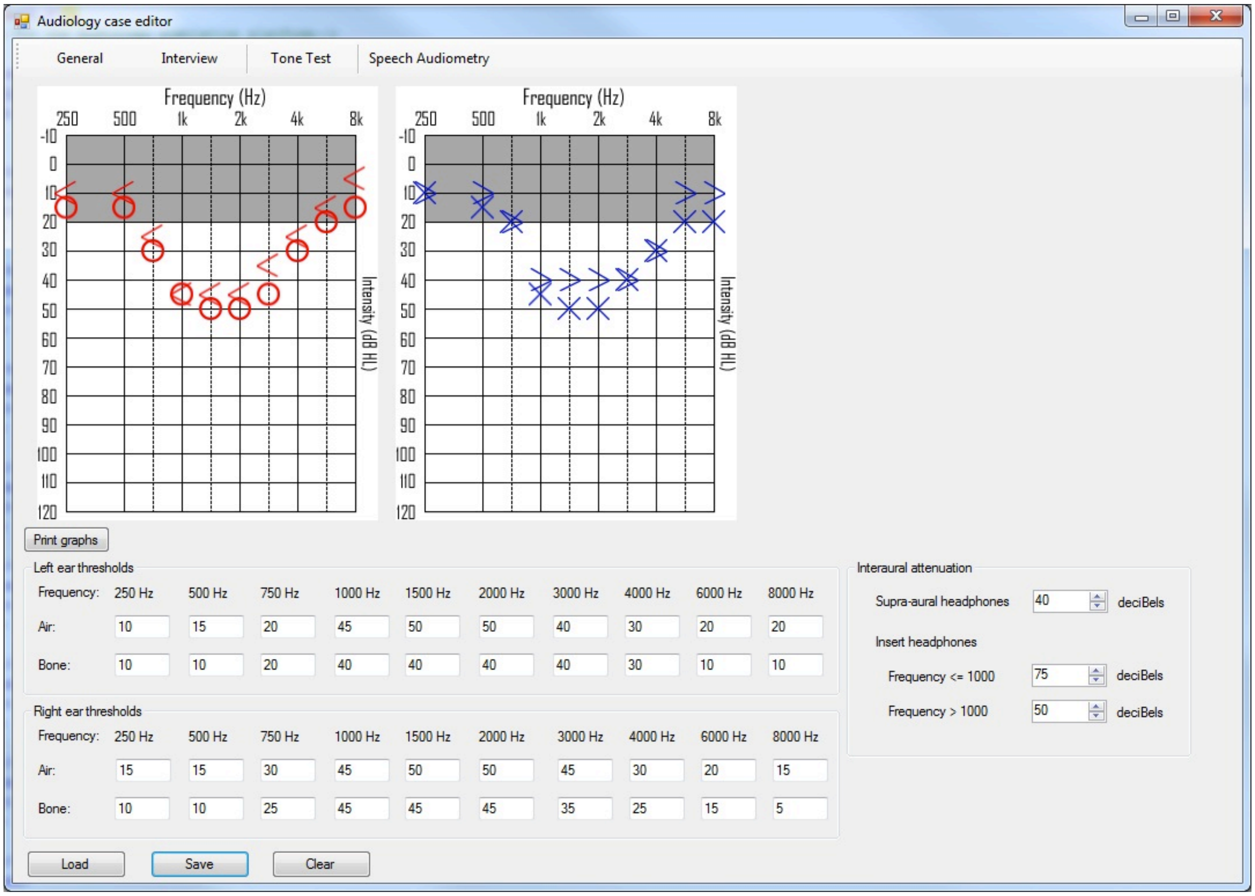
Appendix 6: Copy of the audiograms for each Virtual Patient



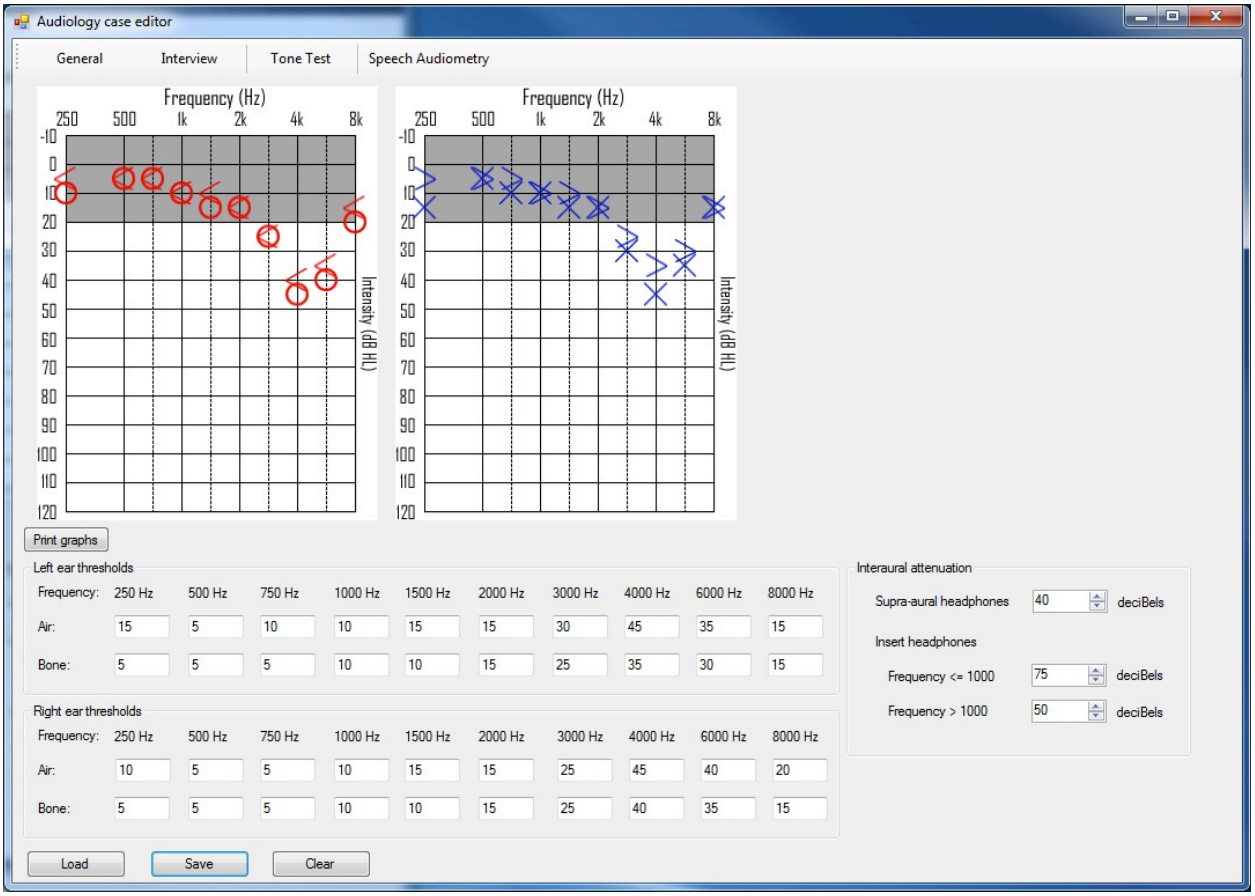
Patient 1


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 15 15 20 20 20 25 30 35 45 50
Bone: 15 15 20 20 20 20 25 25 40 50
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 20 20 20 20 20 20 30 40 50 50
Bone: 20 20 20 20 20 20 30 30 45 50
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

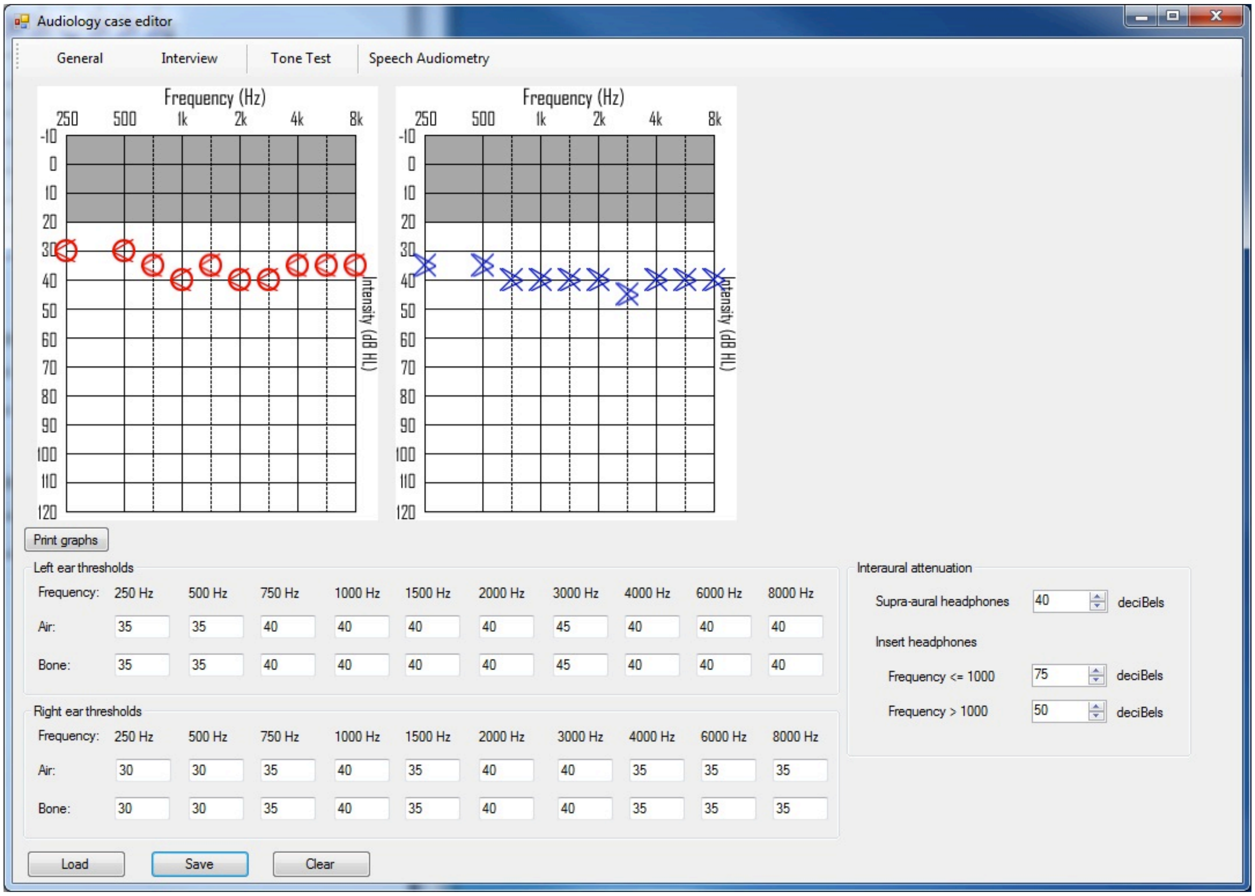
Patient 2


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 15 20 45 50 50 40 30 20 20
Bone: 10 10 20 40 40 40 40 30 10 10
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 15 15 30 45 50 50 45 30 20 15
Bone: 10 10 25 45 45 45 35 25 15 5
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

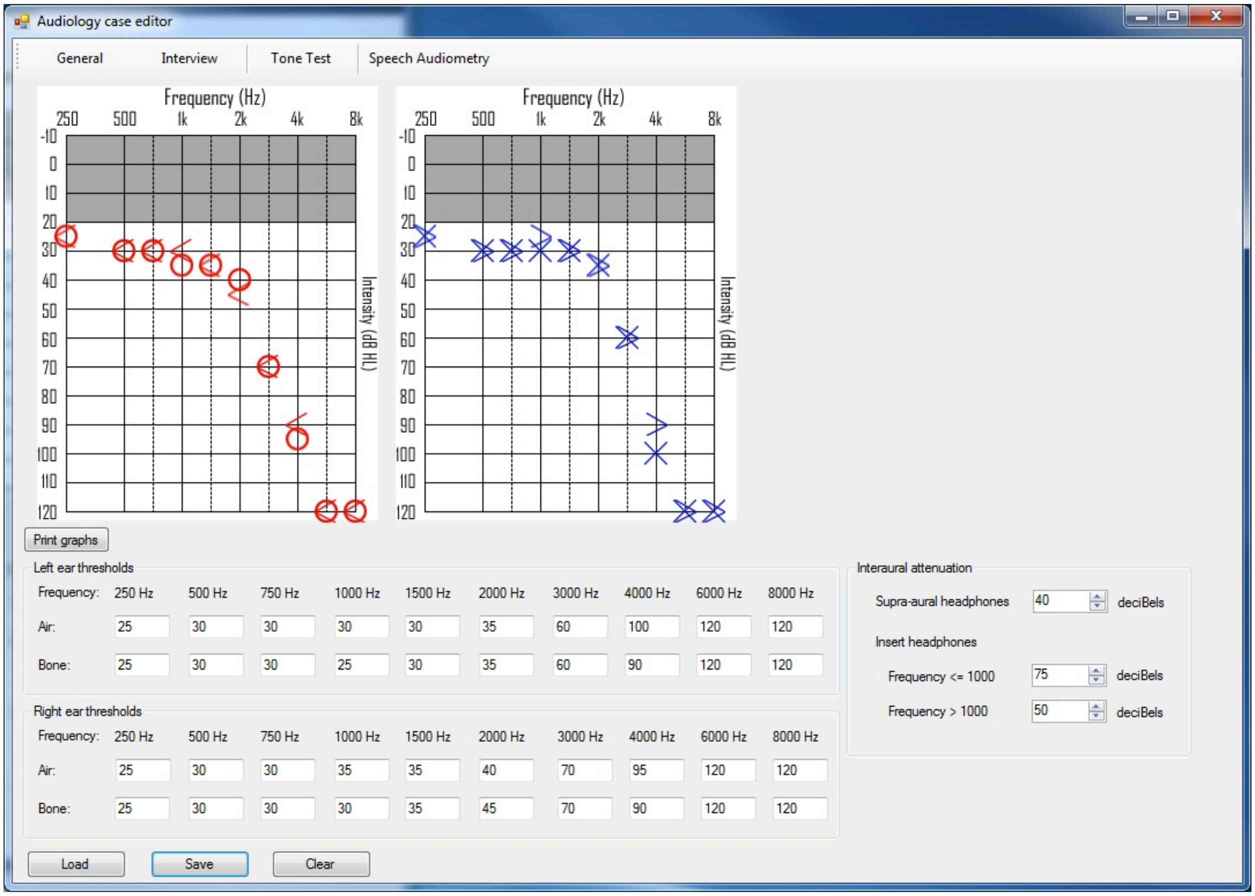
Patient 3


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 15 5 10 10 15 15 30 45 35 15
Bone: 5 5 5 10 10 15 25 35 30 15
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 5 5 10 15 15 25 45 40 20
Bone: 5 5 5 10 10 15 25 40 35 15
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

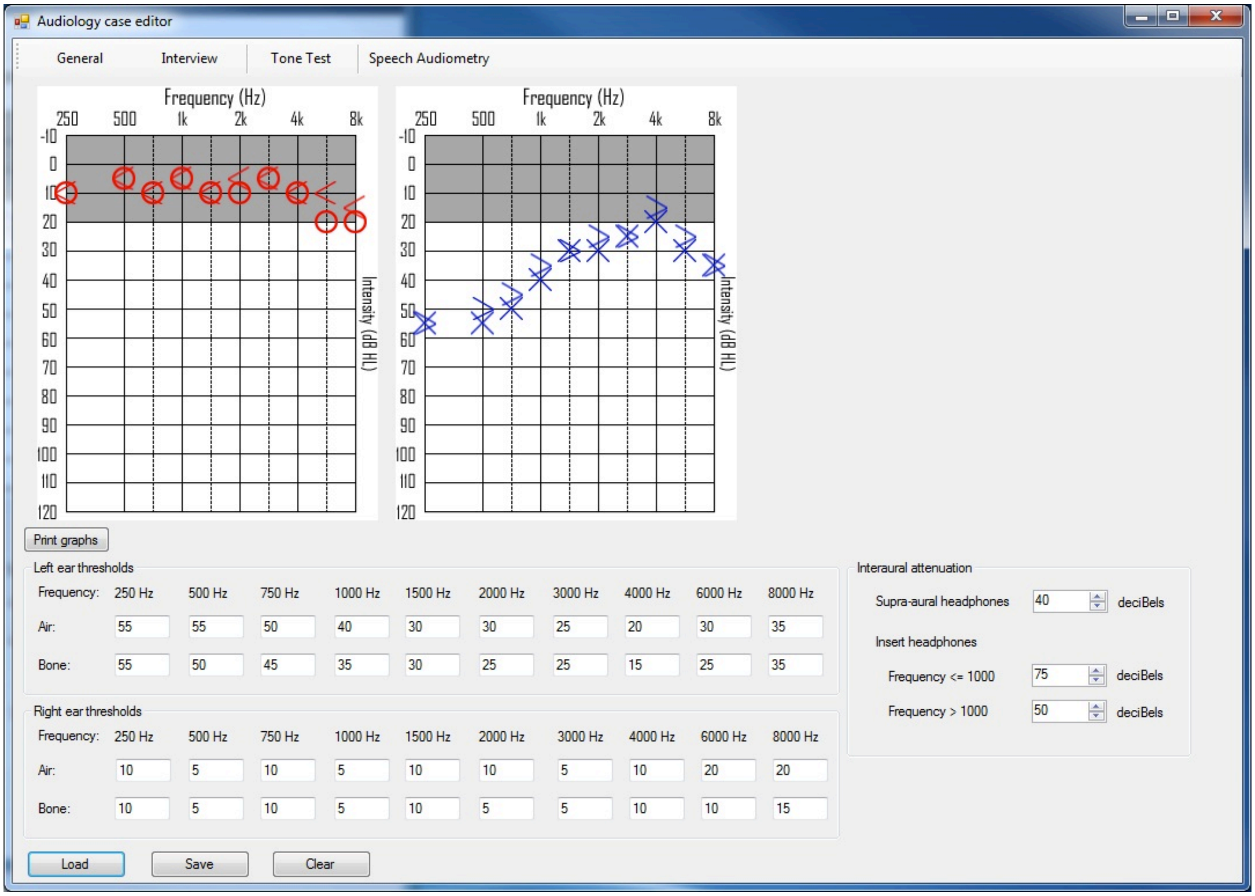
Patient 4


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 35 35 40 40 40 40 45 40 40 40
Bone: 35 35 40 40 40 40 45 40 40 40
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 30 30 35 40 35 40 40 35 35 35
Bone: 30 30 35 40 35 40 40 35 35 35
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

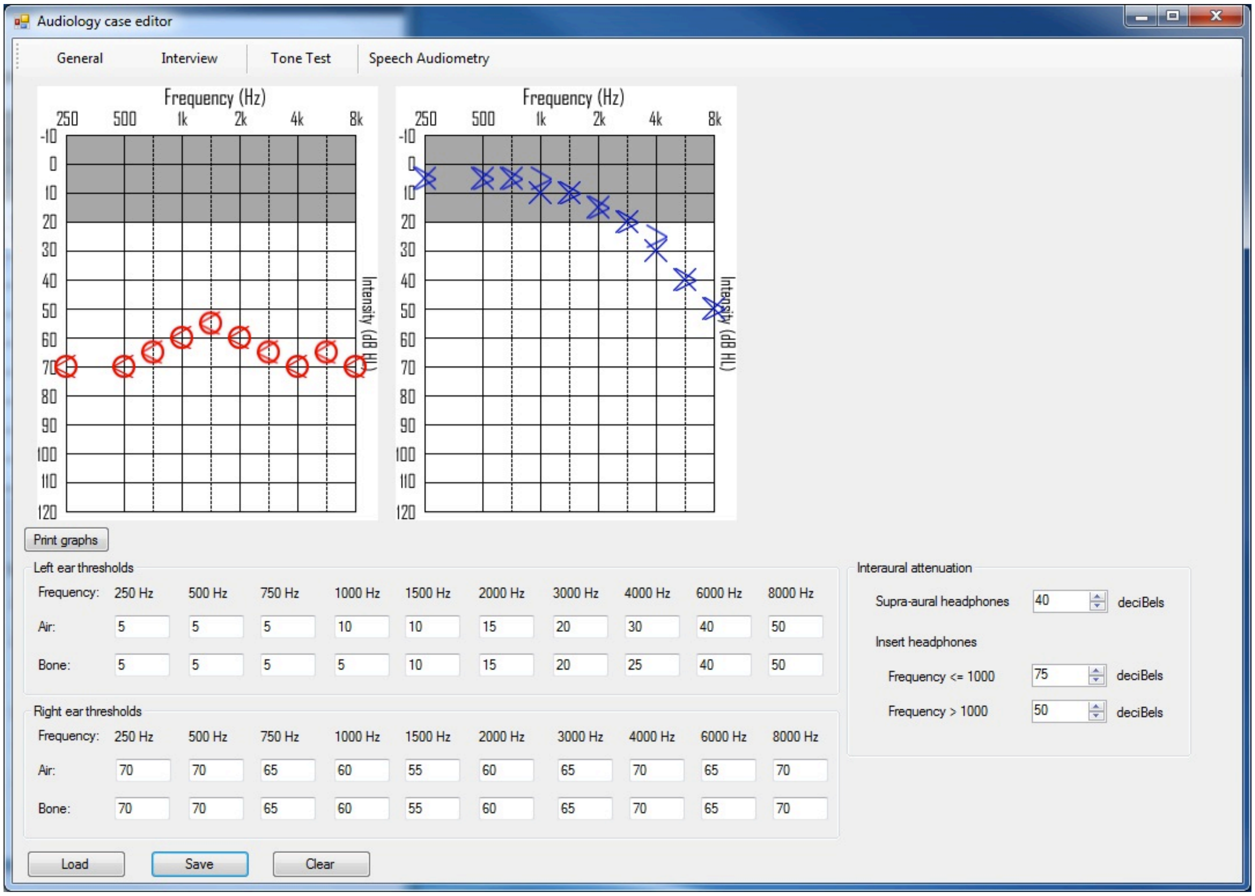
Patient 5


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 25 30 30 30 30 35 60 100 120 120
Bone: 25 30 30 25 30 35 60 90 120 120
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 25 30 30 35 35 40 70 95 120 120
Bone: 25 30 30 30 35 45 70 90 120 120
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

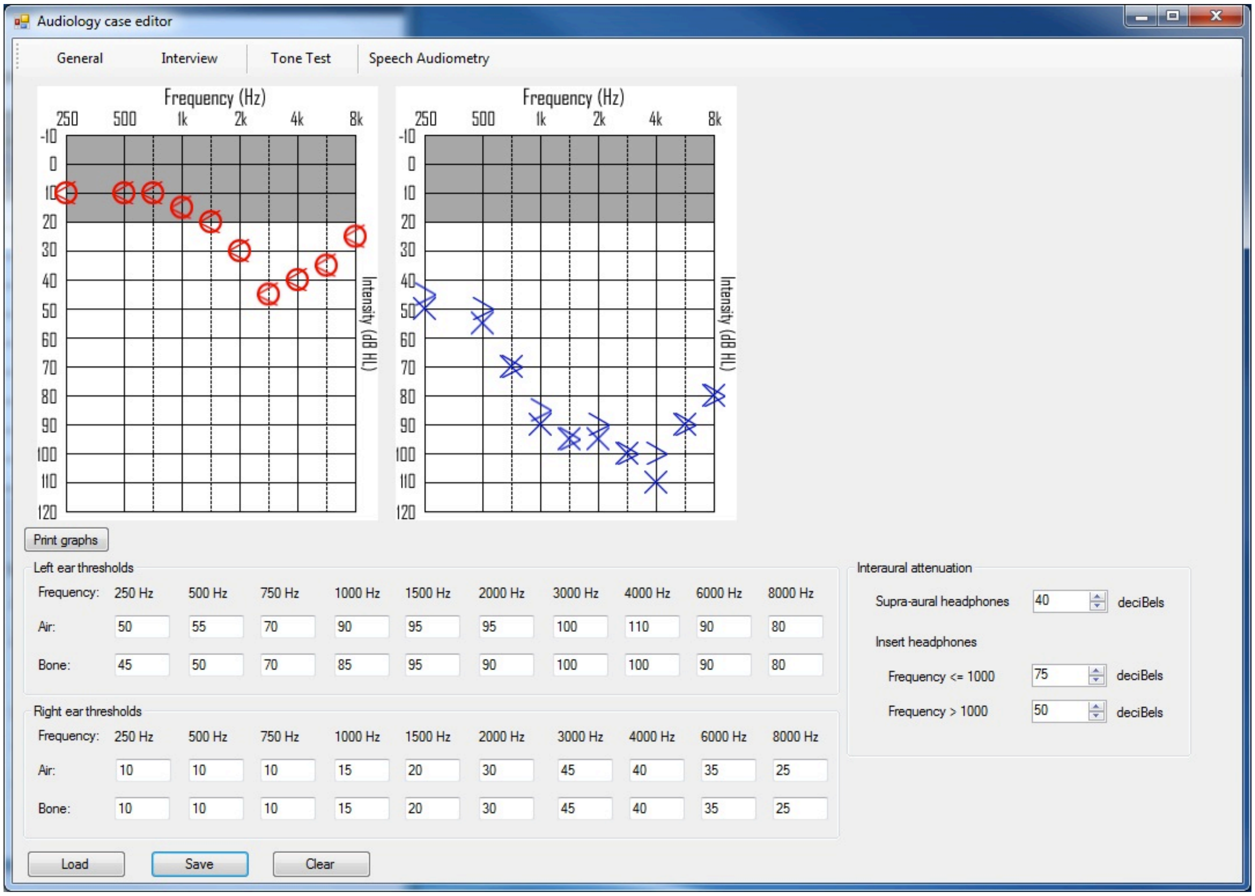
Patient 6


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 55 55 50 40 30 30 25 20 30 35
Bone: 55 50 45 35 30 25 25 15 25 35
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 5 10 5 10 10 5 10 20 20
Bone: 10 5 10 5 10 5 5 10 10 15
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

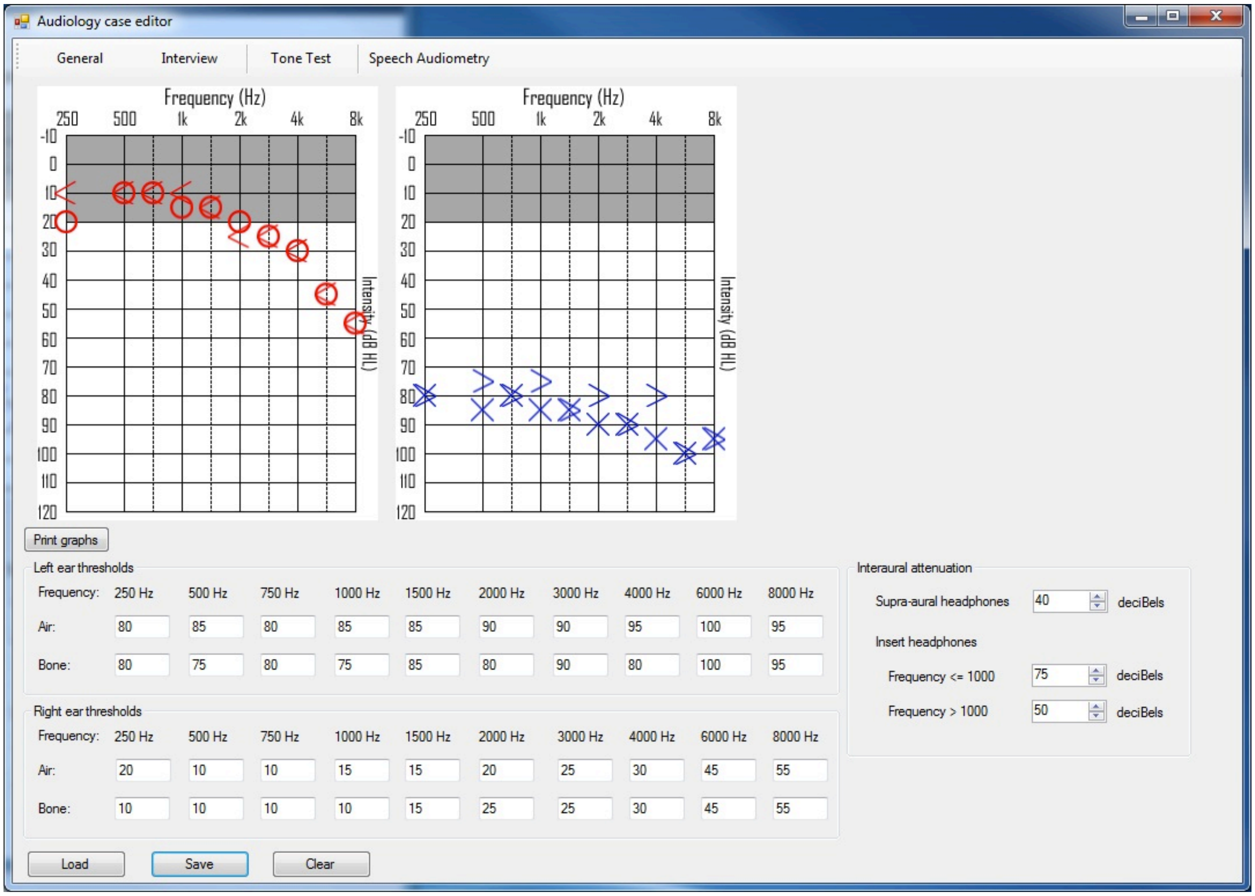
Patient 7


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 5 5 5 10 10 15 20 30 40 50
Bone: 5 5 5 5 10 15 20 25 40 50
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 70 70 65 60 55 60 65 70 65 70
Bone: 70 70 65 60 55 60 65 70 65 70
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

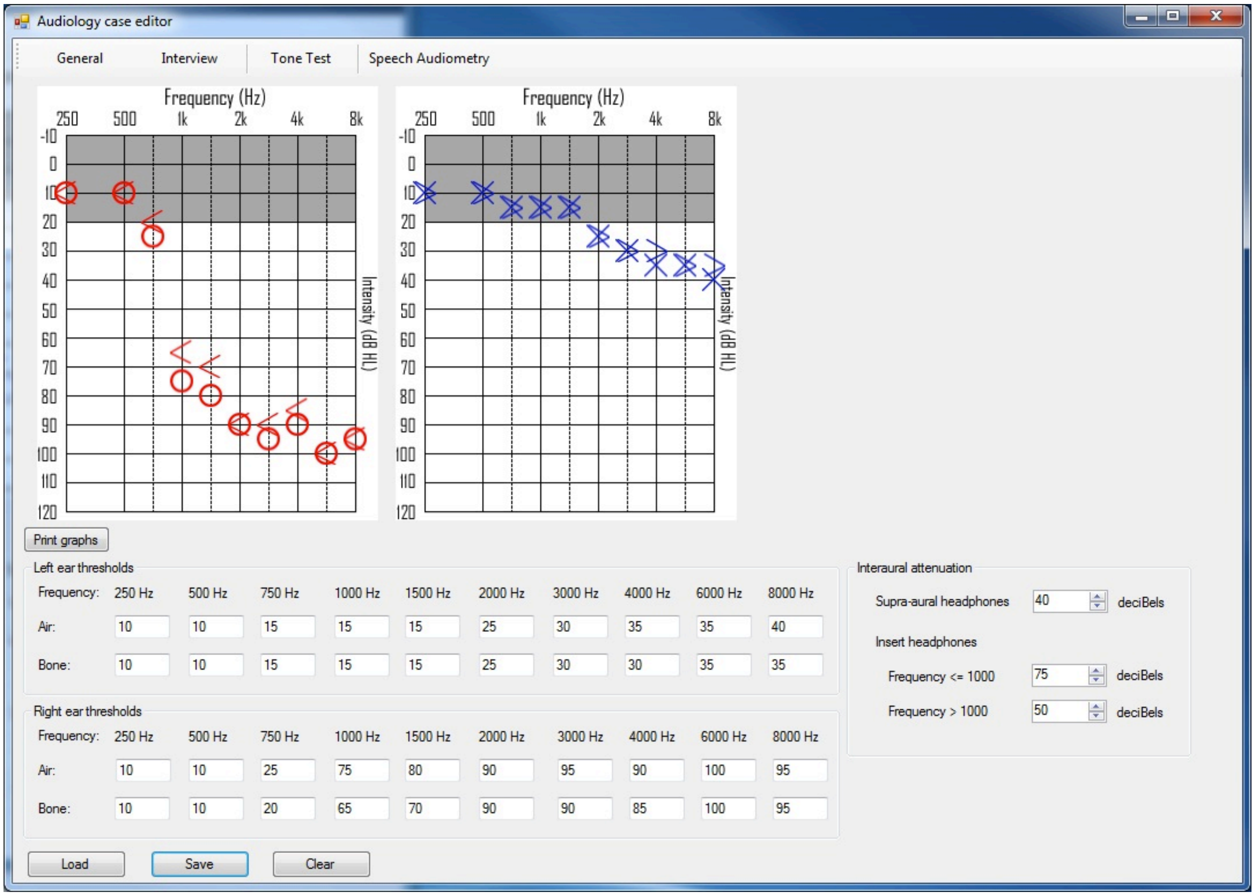
Patient 8


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 50 55 70 90 95 95 100 110 90 80
Bone: 45 50 70 85 95 90 100 100 90 80
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 10 15 20 30 45 40 35 25
Bone: 10 10 10 15 20 30 45 40 35 25
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

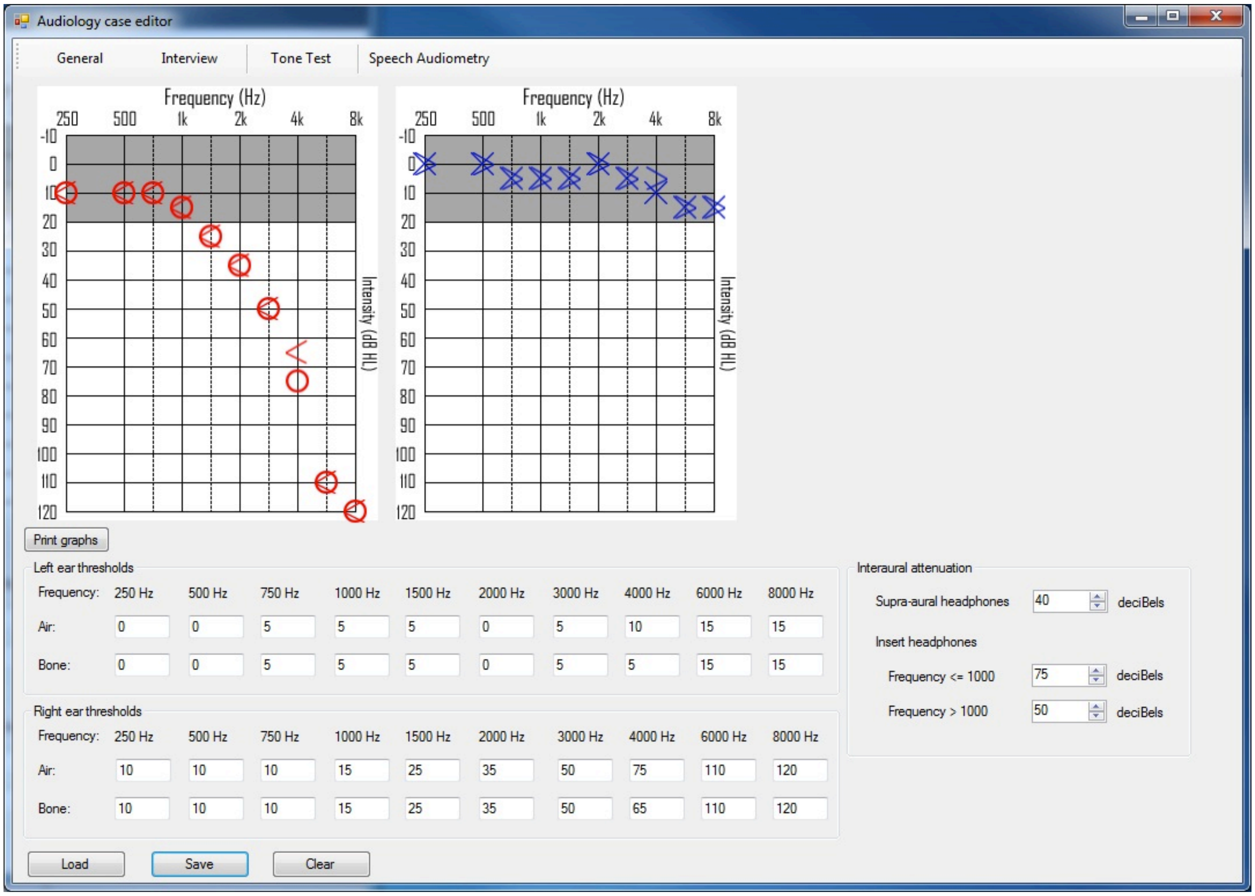
Patient 9


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 80 85 80 85 85 90 90 95 100 95
Bone: 80 75 80 75 85 80 90 80 100 95
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 20 10 10 15 15 20 25 30 45 55
Bone: 10 10 10 10 15 25 25 30 45 55
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

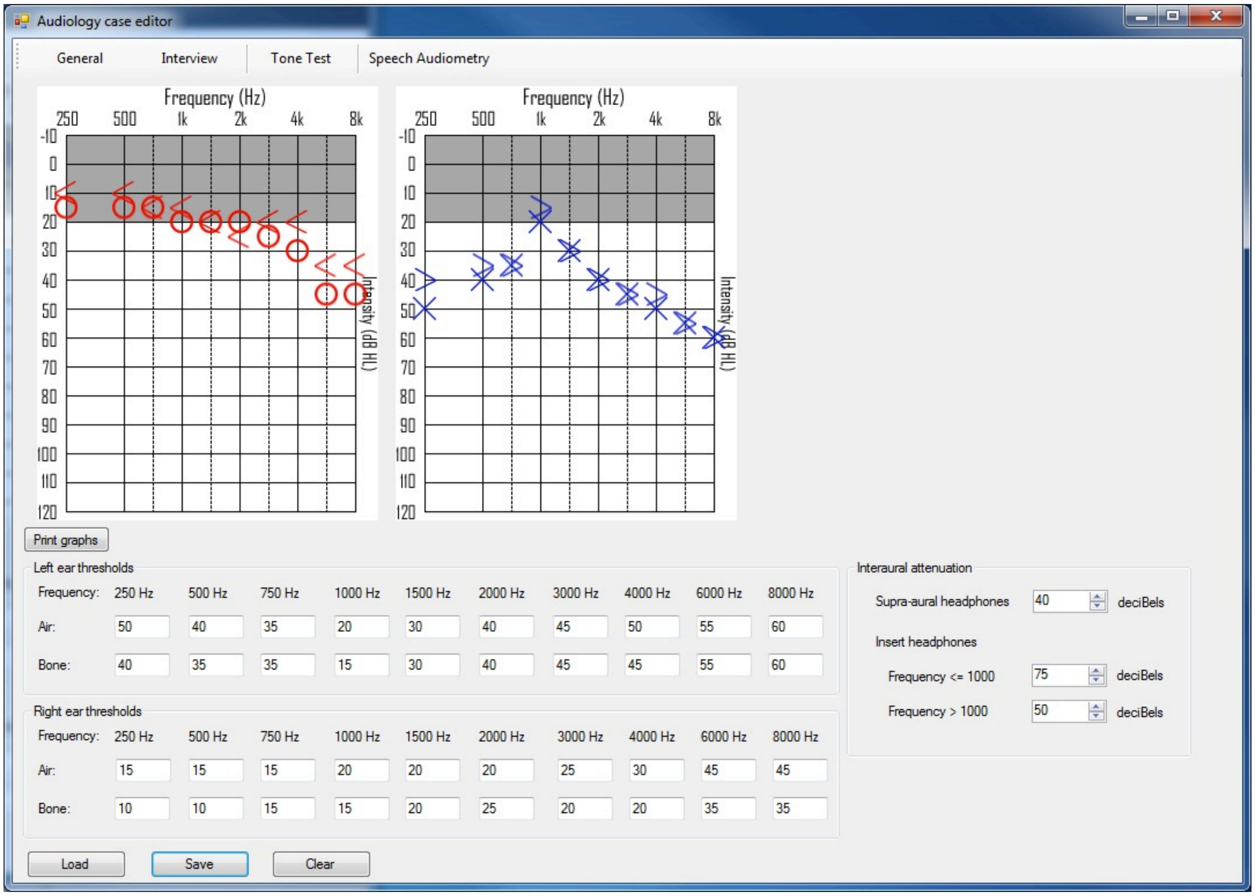
Patient 10


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 15 15 15 25 30 35 35 40
Bone: 10 10 15 15 15 25 30 30 35 35
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 25 75 80 90 95 90 100 95
Bone: 10 10 20 65 70 90 90 85 100 95
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

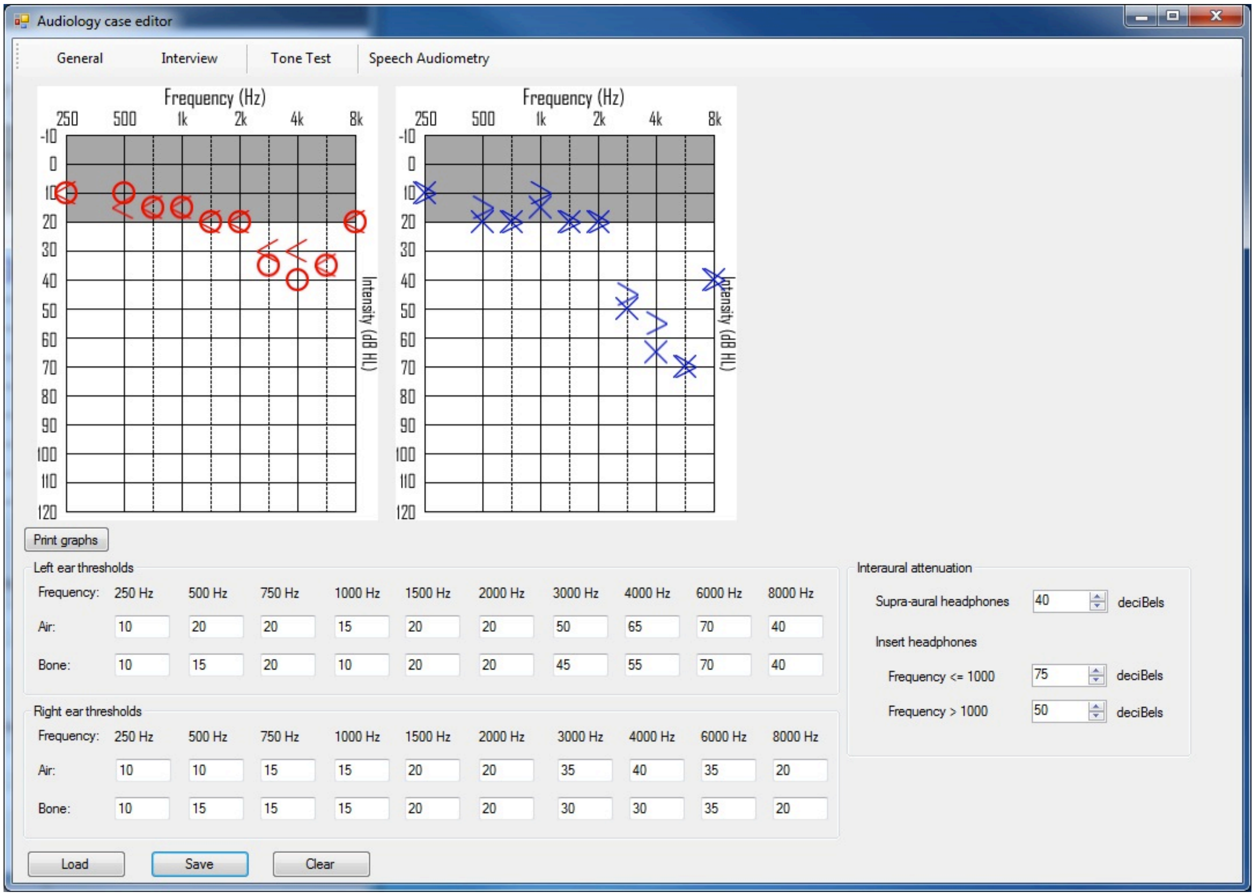
Patient 11


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 0 0 5 5 5 0 5 10 15 15
Bone: 0 0 5 5 5 0 5 5 15 15
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 10 15 25 35 50 75 110 120
Bone: 10 10 10 15 25 35 50 65 110 120
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

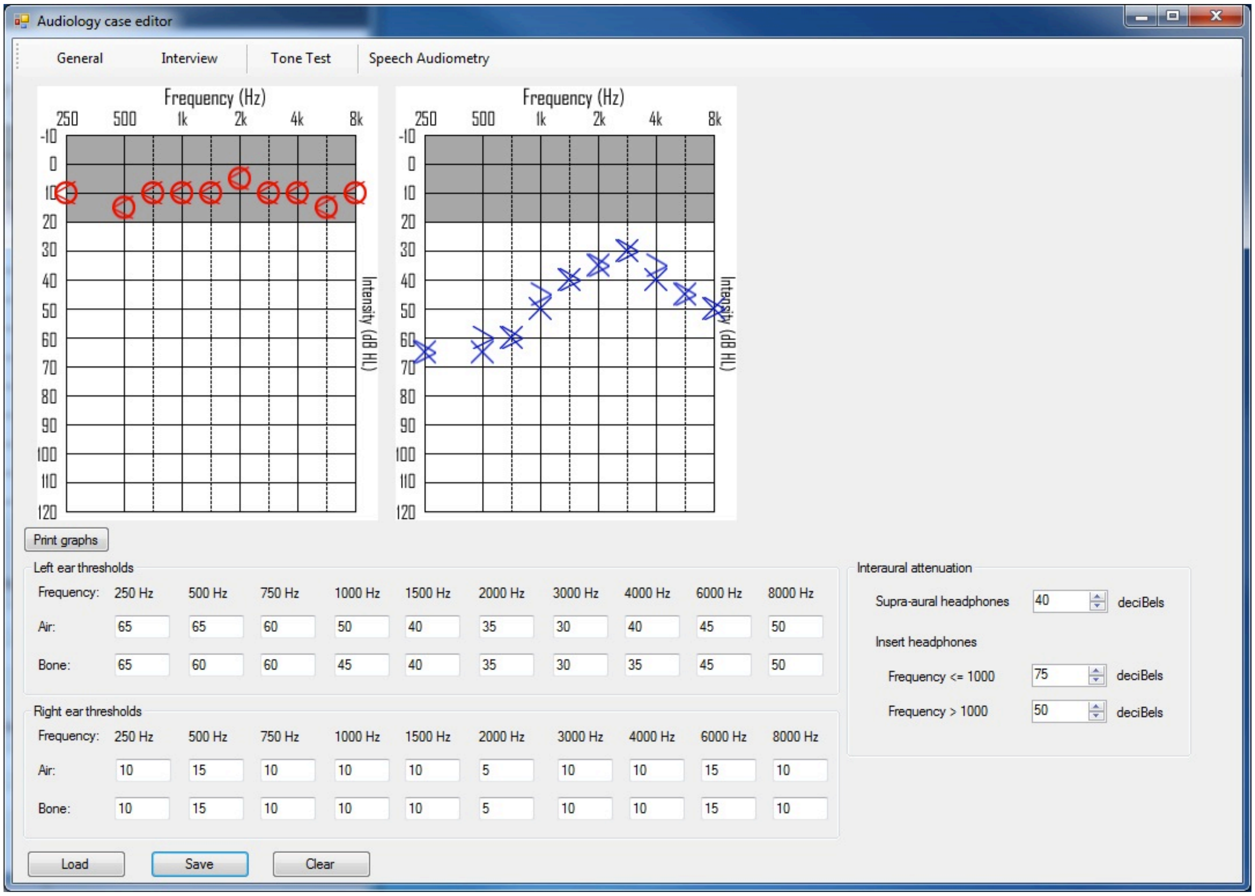
Patient 12


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 50 40 35 20 30 40 45 50 55 60
Bone: 40 35 35 15 30 40 45 45 55 60
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 15 15 15 20 20 20 25 30 45 45
Bone: 10 10 15 15 20 25 20 20 35 35
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

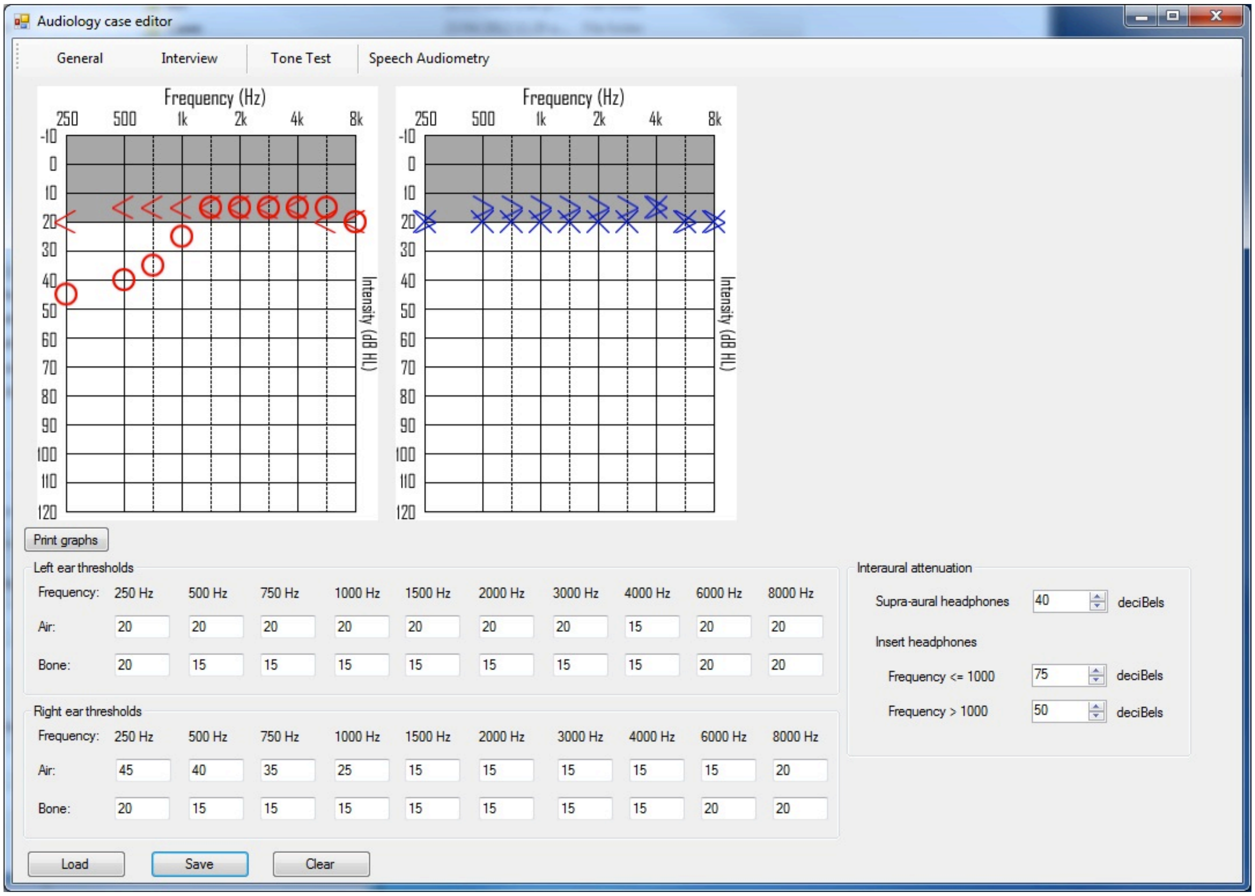
Patient 13


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 20 20 15 20 20 50 65 70 40
Bone: 10 15 20 10 20 20 45 55 70 40
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 15 15 20 20 35 40 35 20
Bone: 10 15 15 15 20 20 30 30 35 20
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 14

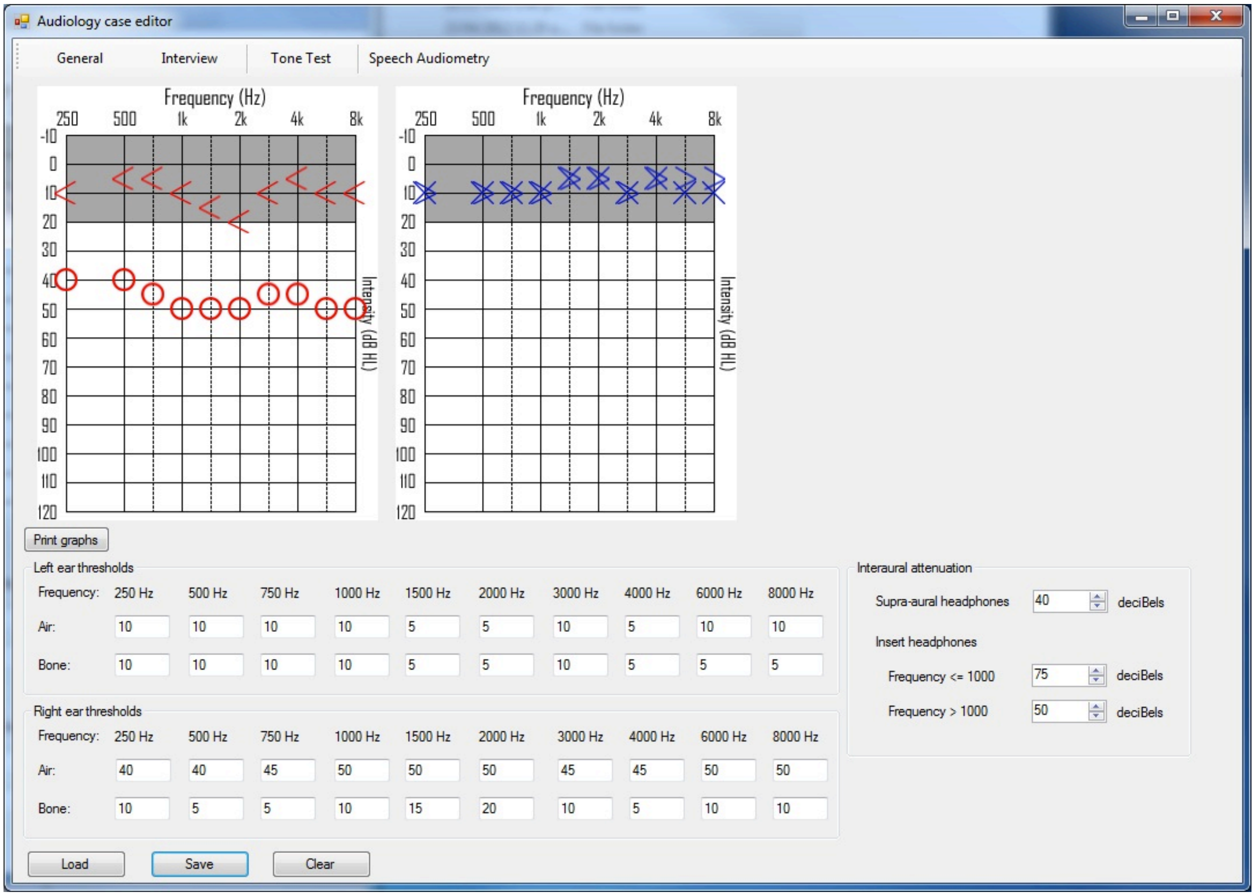

Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 65 65 60 50 40 35 30 40 45 50
Bone: 65 60 60 45 40 35 30 35 45 50
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 15 10 10 10 5 10 10 15 10
Bone: 10 15 10 10 10 5 10 10 15 10
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 15

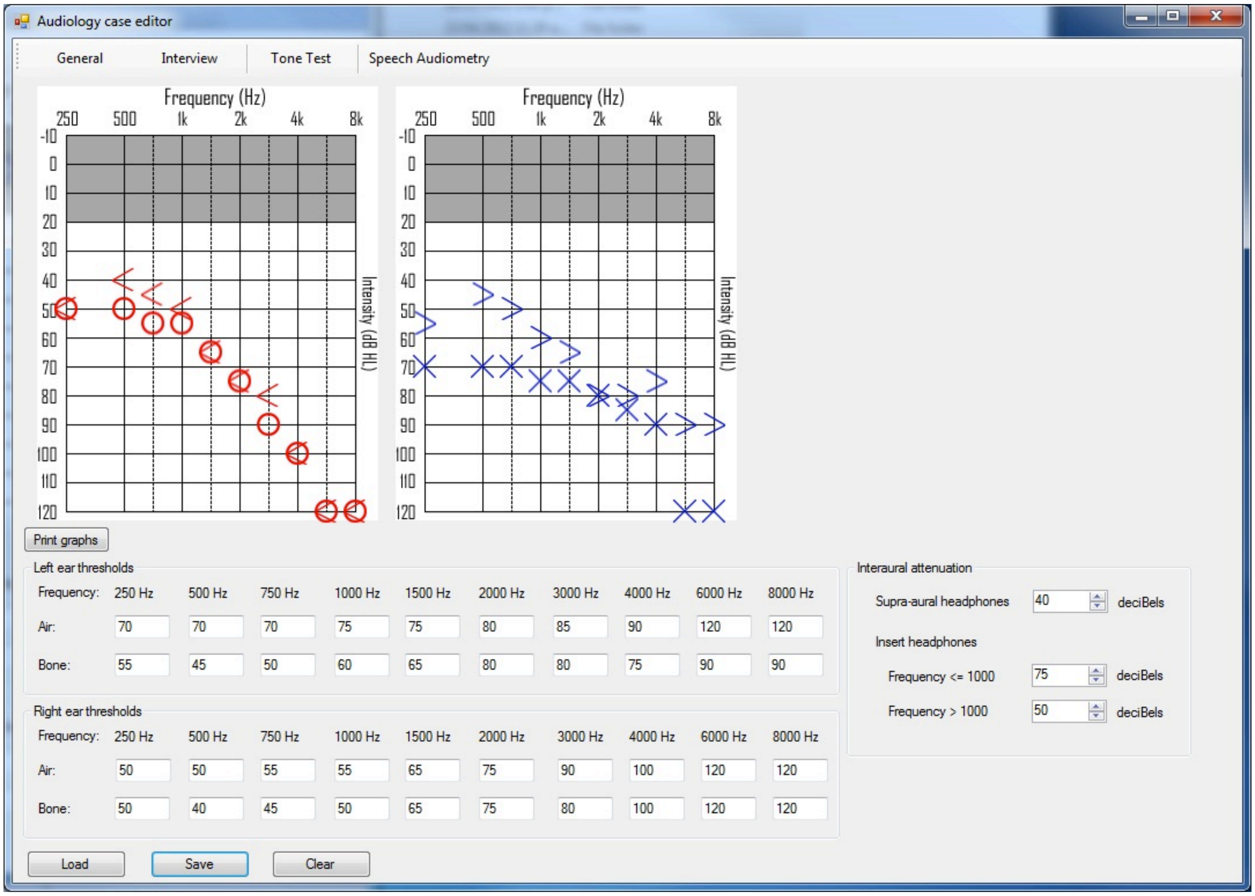


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 20 20 20 20 20 20 20 15 20 20
Bone: 20 15 15 15 15 15 15 15 20 20
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 45 40 35 25 15 15 15 15 15 20
Bone: 20 15 15 15 15 15 15 15 20 20
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

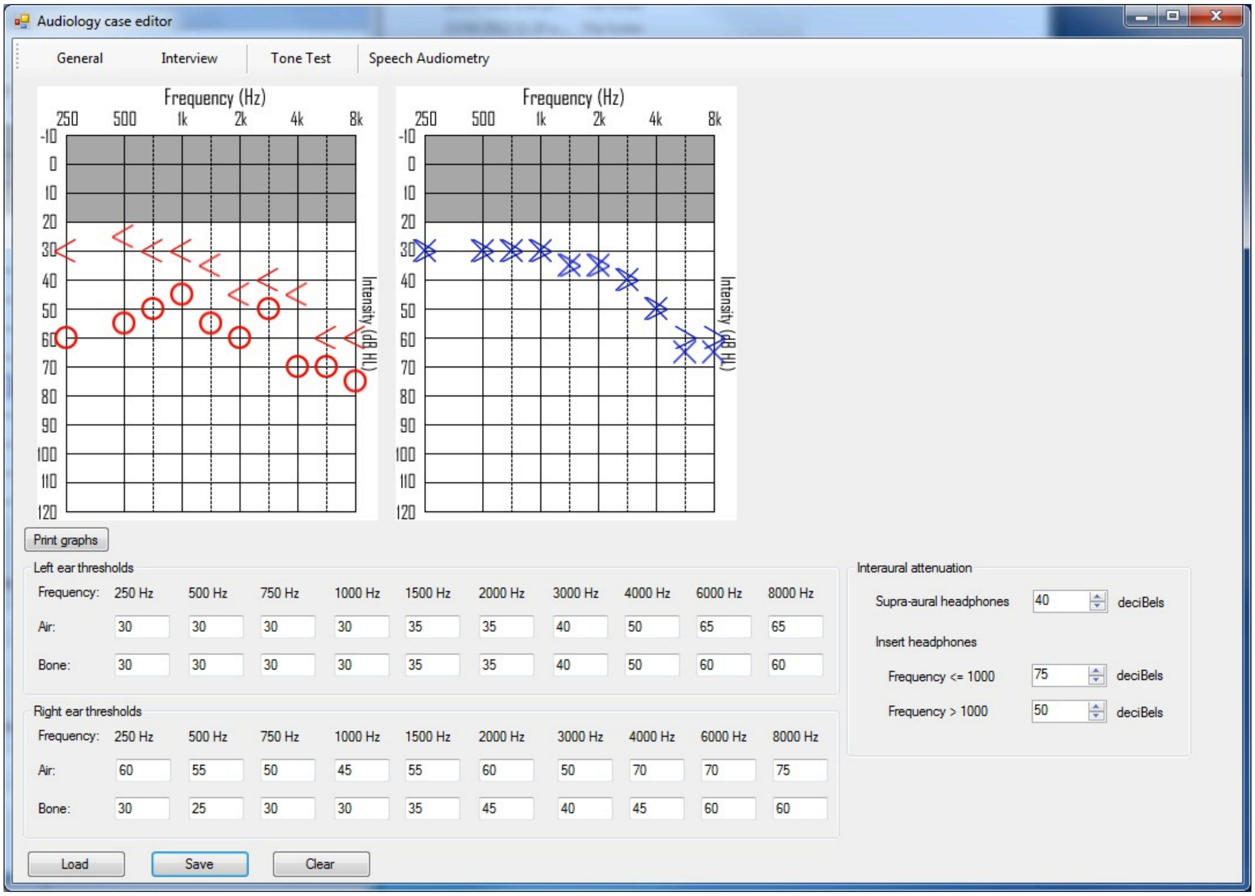
Patient 16


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 10 10 5 5 10 5 10 10
Bone: 10 10 10 10 5 5 10 5 5 5
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 40 40 45 50 50 50 45 45 50 50
Bone: 10 5 5 10 15 20 10 5 10 10
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

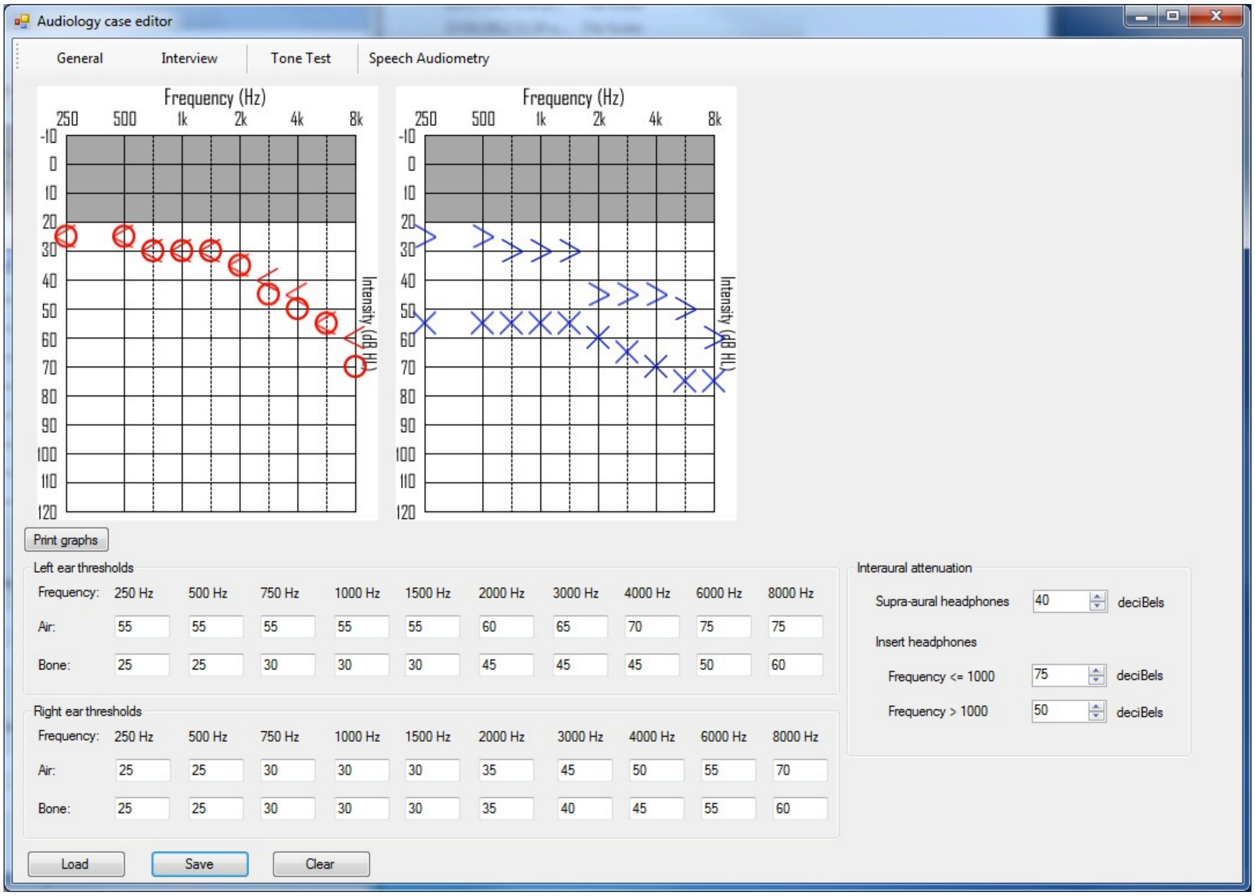
Patient 17


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 70 70 70 75 75 80 85 90 120 120
Bone: 55 45 50 60 65 80 80 75 90 90
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 50 50 55 55 65 75 90 100 120 120
Bone: 50 40 45 50 65 75 80 100 120 120
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

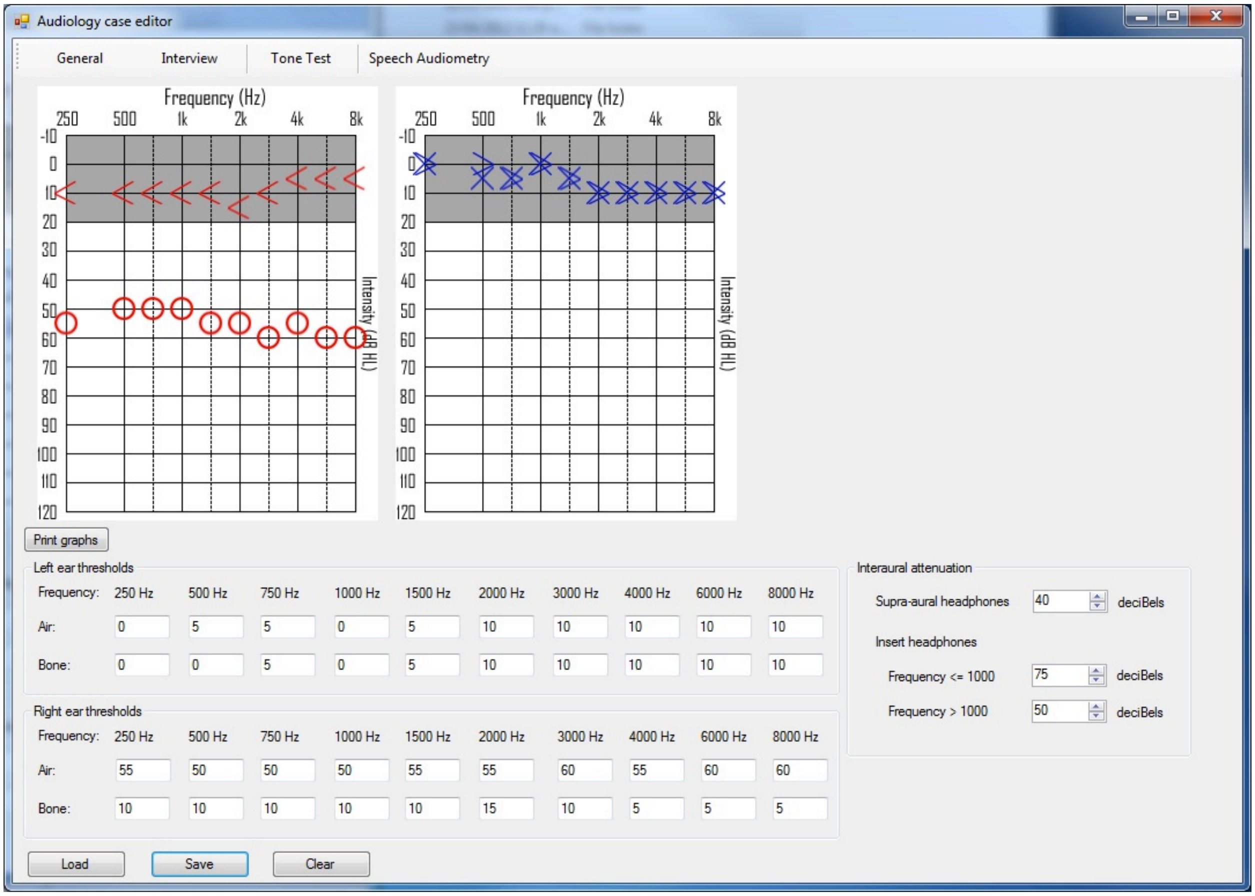
Patient 18


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 30 30 30 30 35 35 40 50 65 65
Bone: 30 30 30 30 35 35 40 50 60 60
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 60 55 50 45 55 60 50 70 70 75
Bone: 30 25 30 30 35 45 40 45 60 60
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

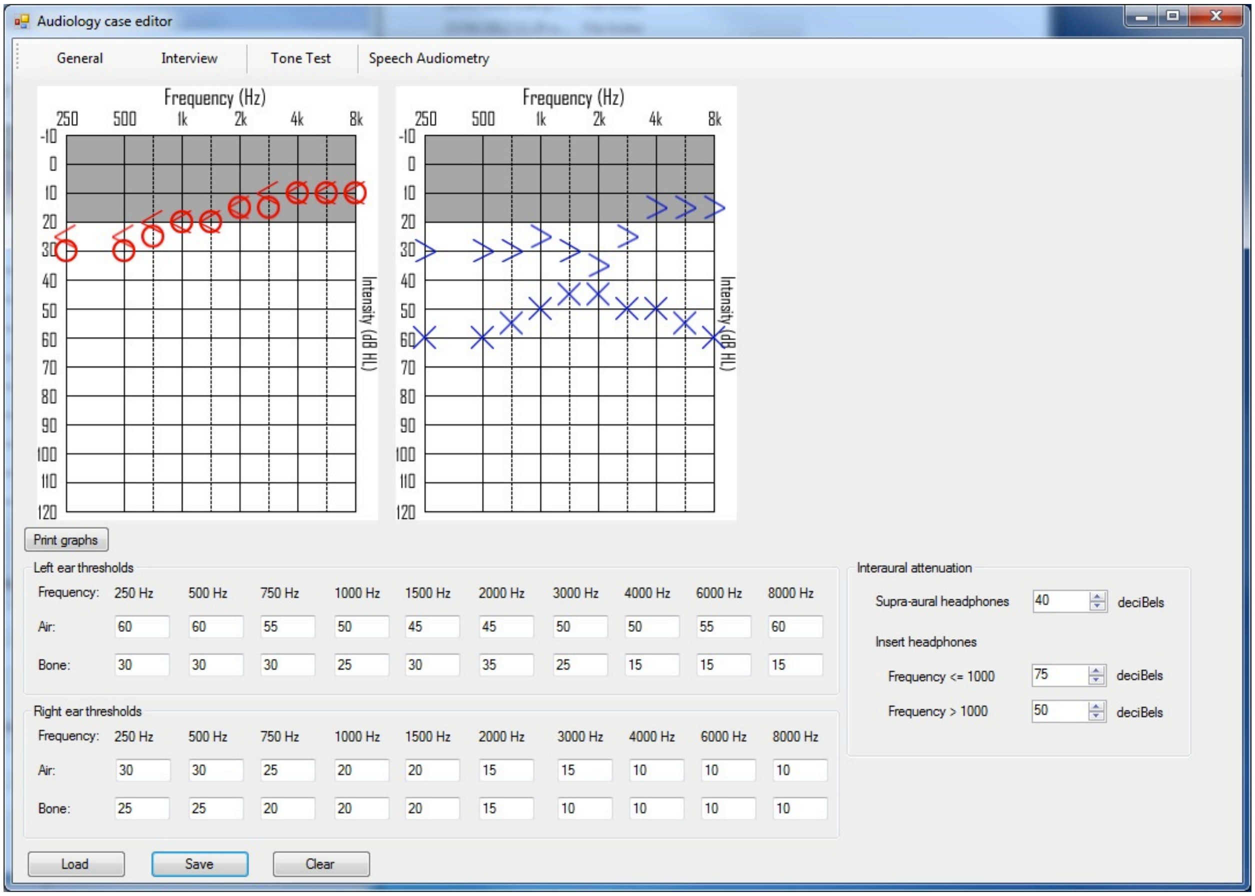
Patient 19


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 55 55 55 55 55 60 65 70 75 75
Bone: 25 25 30 30 30 45 45 45 50 60
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 25 25 30 30 30 35 45 50 55 70
Bone: 25 25 30 30 30 35 40 45 55 60
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

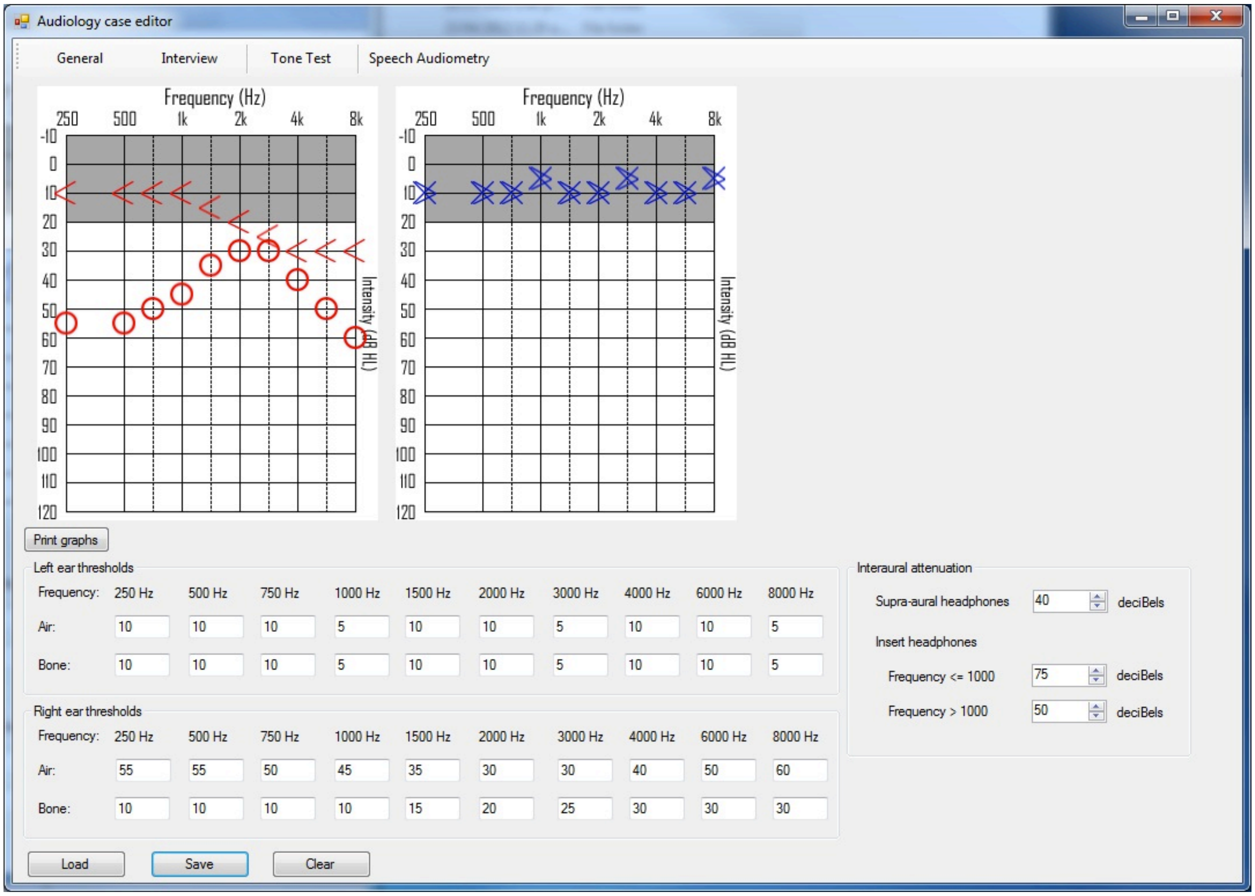
Patient 20


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 0 5 5 0 5 10 10 10 10 10
Bone: 0 0 5 0 5 10 10 10 10 10
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 55 50 50 50 55 55 60 55 60 60
Bone: 10 10 10 10 10 15 10 5 5 5
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 21

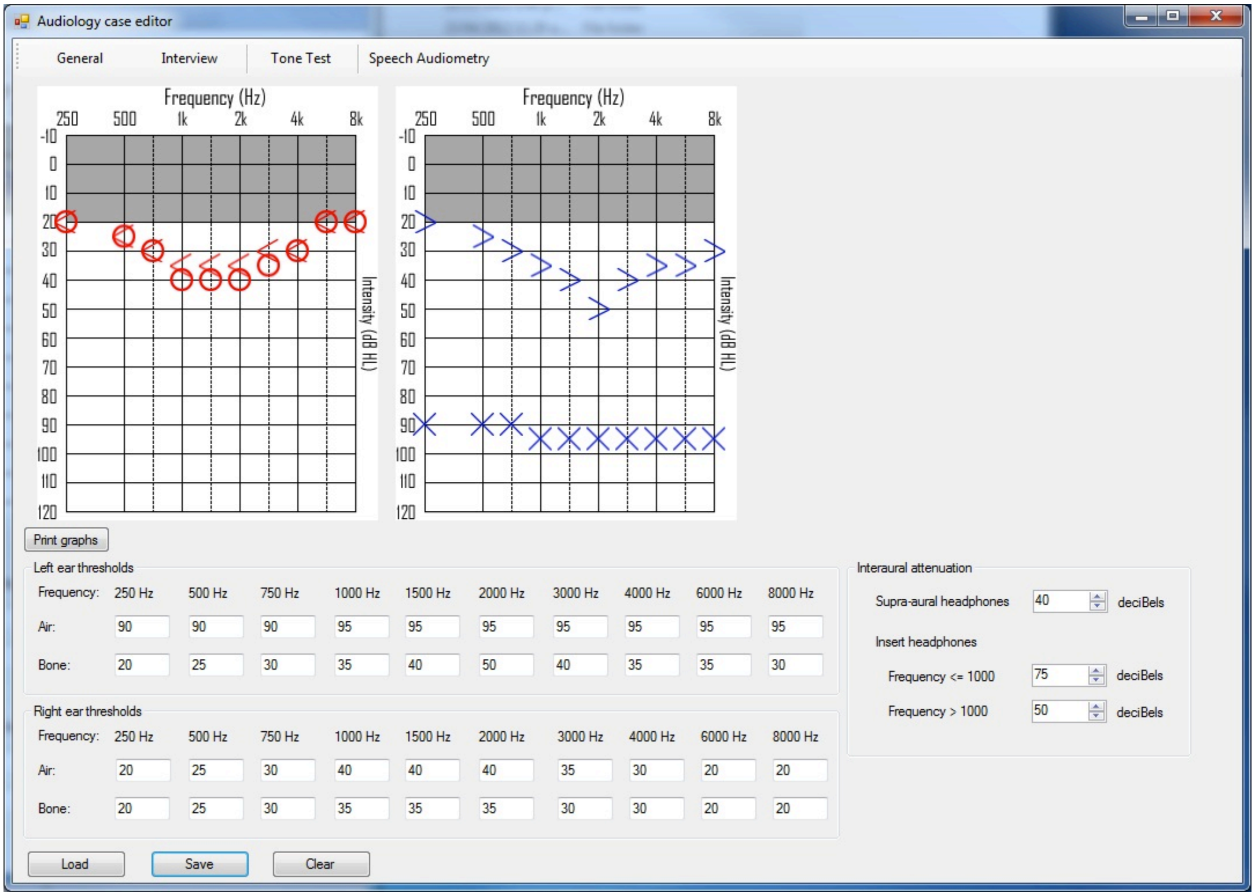

Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 60 60 55 50 45 45 50 50 55 60
Bone: 30 30 30 25 30 35 25 15 15 15
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 30 30 25 20 20 15 15 10 10 10
Bone: 25 25 20 20 20 15 10 10 10 10
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 22

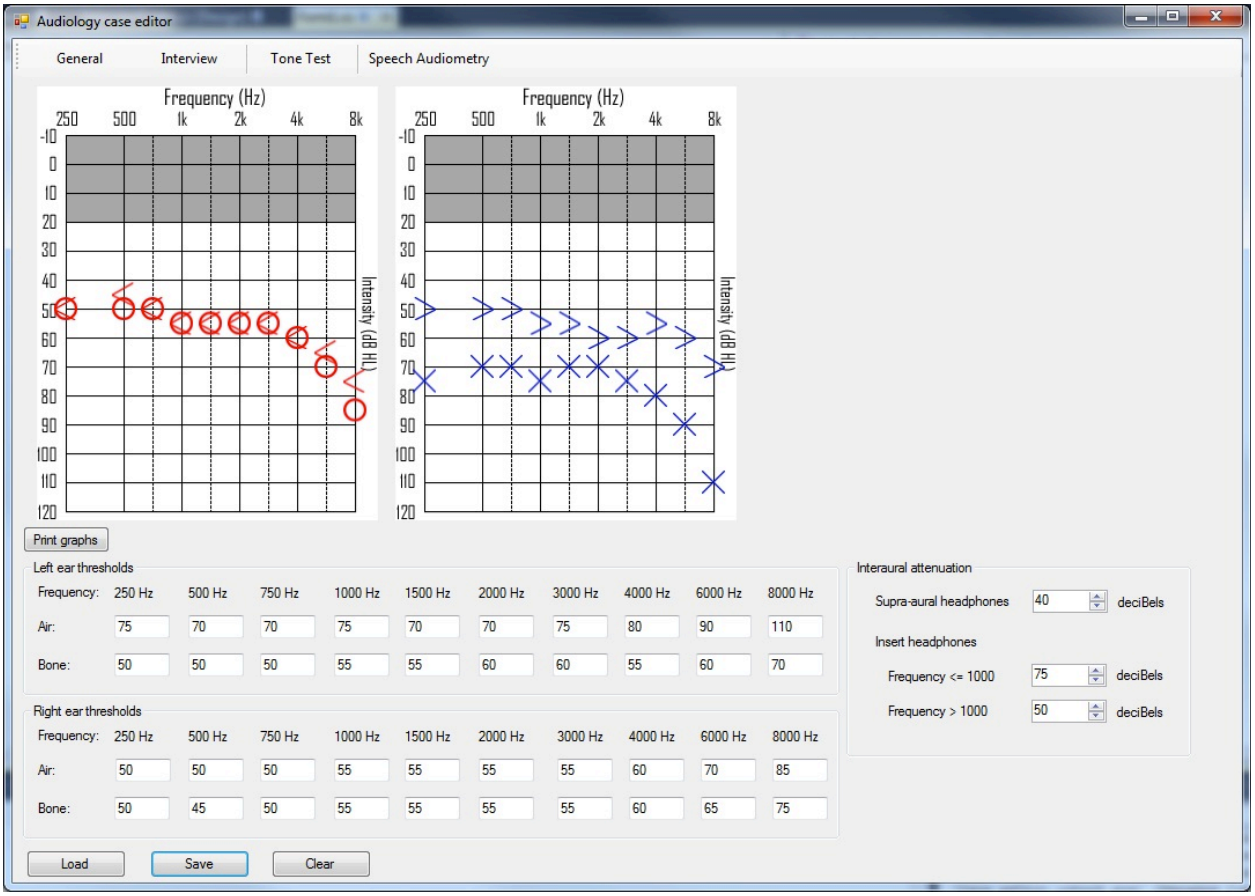


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 10 10 10 5 10 10 5 10 10 5
Bone: 10 10 10 5 10 10 5 10 10 5
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 55 55 50 45 35 30 30 40 50 60
Bone: 10 10 10 10 15 20 25 30 30 30
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 23


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 90 90 90 95 95 95 95 95 95 95
Bone: 20 25 30 35 40 50 40 35 35 30
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 20 25 30 40 40 40 35 30 20 20
Bone: 20 25 30 35 35 35 30 30 20 20
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 24


Audiology case editor
General
Interview
Tone Test
Speech Audiometry
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Frequency (Hz)
250 500 1k 2k 4k 8k
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity (dB HL)
Print graphs
Left ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 75 70 70 75 70 70 75 80 90 110
Bone: 50 50 50 55 55 60 60 55 60 70
Right ear thresholds
Frequency: 250 Hz 500 Hz 750 Hz 1000 Hz 1500 Hz 2000 Hz 3000 Hz 4000 Hz 6000 Hz 8000 Hz
Air: 50 50 50 55 55 55 55 60 70 85
Bone: 50 45 50 55 55 55 55 60 65 75
Interaural attenuation
Supra-aural headphones 40 deciBels
Insert headphones
Frequency <= 1000 75 deciBels
Frequency > 1000 50 deciBels
Load
Save
Clear

Patient 25